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EDITORIAL NOTES.

THE appearance of a new part (No. 20) of *Geological Literature added to the Geological Society's Library* in 1913 will be welcomed by all who are actively engaged in geological work. In the interests of research it is to be hoped that the issue of the records for 1914 and subsequent years will not be long delayed, as this publication is of the greatest possible value, in fact one might almost say indispensable to all who desire to keep up with the current developments of their particular branch of the subject. Our thanks are due to the anonymous compiler of this part; only those who have had experience in bibliographical work can form any idea of the amount of time and trouble which its preparation must have involved.

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DURING the year 1921–22 Geophysical Discussions of the Royal Astronomical Society will take place on the first Friday in November, December, February, March, and May. In each case the meeting will begin at 5 p.m., and tea will be provided at 4.30. On 4th November Col. H. G. Lyons will open a discussion on the Eötvös Gravity Balance. On 2nd December Dr. Harold Jeffreys will open a discussion on the Cooling of the Earth and its Geological Effects. Fuller particulars of the meetings will appear in *Nature*, or can be obtained on application to the Assistant Secretary, Royal Astronomical Society, Burlington House, London, W. 1. All members of the Geological Society are invited.

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IN comparison with the amount of attention bestowed on the nomenclature of the igneous rocks, that of the sediments has been comparatively neglected. All field-workers in stratigraphical geology must have been often conscious of a want of precision in the terms at their disposal for the description of the rock-types encountered in the course of their work. This applies perhaps with the greatest force to the arenaceous types of sediment. The special point that we have in mind is the want of a satisfactory field-term to describe the very hard fine-grained rocks that are so abundant for example in the Silurian system in most parts of this country. These are generally called *grits*, but this is a misapplication of the

word. The essential feature of a true grit is that it should be gritty, that is, breaking and weathering with a rough uneven surface, which these rocks do not. A true grit, such as the Millstone Grit, is of very irregular grain, and usually more or less porous, whereas the Silurian rocks here referred to are of very fine texture, even-grained, and very closely and tightly cemented. The name sandstone is hardly applicable, since to most people it connotes the idea of a somewhat soft and crumbly rock. The old term greywacke is better, but unfortunately it is not English. What is wanted is a good Anglo-Saxon word, not already used in some other quite different sense, and if possible self-explanatory. During the present field-season we commend this problem to our readers, and shall be glad to receive any communications on the subject that may suggest themselves. There are other problems of a similar nature; for example, What is a quartzite? Is a marl necessarily calcareous? And so on. Many more will no doubt occur to our readers. However, let the discussion, if any, be confined to one at a time.

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It is quite obvious that in geological research work two sets of names are required. One, of a rough and ready character, for use in the field; the other, for detailed petrographical descriptions in the laboratory. Among the igneous rocks we have excellent examples of the first class in the good old names felsite and greenstone. It is true that felsite is a barbarous word, but it is consecrated by usage, while greenstone is eminently descriptive, and both are well adapted for field notes. Later on, the rock can be examined and analyzed and assigned to its proper pigeon-hole in the system of petrographic nomenclature specially fancied by the writer. Most of the common names for the sediments do fulfil the requirements of field-work, but there are not quite enough of them, so that many are used in more than one sense. Every one is acquainted with the trouble caused by endeavours to find out what is really meant by *schiste* and *Schiefer*, and the two senses of the word cleavage are a perpetual stumbling-block to beginners. We are far from wishing to increase the number of technical words or of words used with technical meanings in addition to their ordinary significance, but it is evident that a few more are really needed.

ORIGINAL ARTICLES.

The Jurassic and Lower Cretaceous Rocks of Northern Sinai.[1]

By W. F. Hume, D.Sc., F.R.S.E., A.R.S.M., R. Fourtau, F. W. Moon, B.E., F.G.S., and H. Sadek, B.Sc.

FOR many years this portion of Egypt had remained a blank so far as its geological structure was concerned, and when the geological map of Egypt was issued by the Survey Department in 1910 this extensive area was deliberately left uncoloured. Efforts were made by the writer [2] to interest the various parties which were mapping the topography of this region, but the fossils submitted by them only indicated the presence of beds of Upper Cretaceous age, including a facies identical with that developed in the Abu Roash hills near Cairo.

New and unexpected light was thrown on this problem when M. J. Barthoux commenced a geological map of the Isthmus of Suez on behalf of the Suez Canal Company. He was deeply impressed day by day with a sight of the unknown hills lying behind the sand-dune belt to the east, and finally resolved to cross the waste and solve the mystery of their structure. His energy and resource (shown later during the war by his escape from Germany after being captured near Soissons) were rewarded with success, for in the collections which he brought to the Cairo Geological Museum for study, M. Fourtau recognized species of sea-urchins of definitely Lower Cretaceous age. This indicated that the locality visited was of exceptional interest, and finally led to the discovery of the now famous Jurassic strata of Gebel Maghara. The species thus identified were *Pseudodiadema libanoticum* de Loriol, *Holectypus macropygus* var. *neocomiensis* Gras, and *Pliotoxaster Collegnoi*, race *orientalis*, Fourtau (R. Fourtau, " Echinides Aptiens d'Égypte et de Syrie," *Bull. de l'Inst. Egypt.* 1913, pp. 43–58). At an early stage in the further examination of this area, M. Barthoux kindly invited the writer to accompany him, but as this was impossible owing to other duties demanding attention, it was arranged for M. Fourtau to join him. This has led to a very careful palæontological and stratigraphical study of the area by M. Fourtau, the results of which will appear in due course.[3] M. Douvillé was associated with M. Barthoux in the earliest publications on this subject, one of the first notes being that on " Le Jurassique dans le désert à l'est de l'isthme de Suez ",

[1] Published by permission of the Surveyor-General, Egyptian Government.

[2] This note has been written by Dr. W. F. Hume (hence termed the writer), but the facts on which it is based largely depend upon the work of those who are associated in the title as co-authors.

[3] Owing to the death of M. Fourtau since these words were written, it is uncertain how far this can be fulfilled, but every effort will be made to publish the work in so far as it was completed by this indefatigable and enthusiastic student, whose early loss to science we lament.

by J. M. Barthoux et M. Douvillé (*Comptes Rendus Ac. Sciences*, t. 157, p. 265, 28th July, 1913).

In this paper it was pointed out that no Jurassic formations were previously known in the south-eastern portion of the Mediterranean basin between Tunis and North Palestine, and that in Sinai itself they are only found in the most northern of the hill ranges, of which Gtera (Gedeira), Hameir (Hamaiyir), and Maghara are the principal component hills. Here, however, there is a notable development,

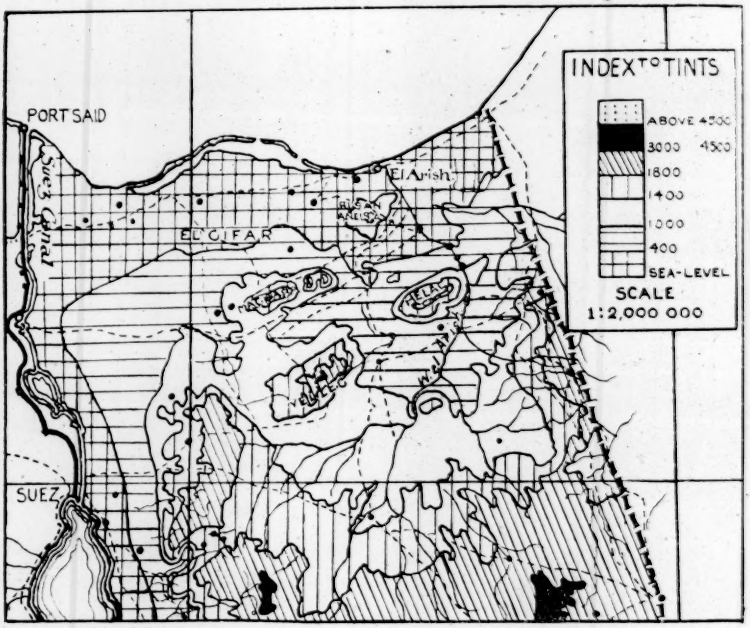

FIG. 1.—Orographic map of Northern Sinai.

the lowest strata being characteristic (*a*) "Nubian Sandstone", with vegetable remains. They are highly inclined, and their base is not seen. These are followed by (*b*) an alternation of grits and marls having an estimated thickness of 80 metres, overlain by greyish limestones (about 25 metres thick), with *Terebratula fimbria*, *Rhynchonella Edwardsi*, and corals of the genera *Thamnastrea* and *Montlivaultia*. These are the first beds of the Bajocian (Inferior Oolite), which are succeeded by limestones becoming yellowish and alternating with marls, their dip diminishing little by little. The fossils are well preserved, but often broken, especially the ammonites, which are somewhat rare, and represented by simple fragments. These beds are grouped by the authors under three divisions, (*c*) those of Bajocian age, with *Cœloceras Humphriesi*, *Terebratula Phillipsi*, *T. perovalis*, etc. (*d*) Bathonian (Great Oolite) with *Œcotraustes subfuscus*, *Pholadomya* cf. *Aubryi*, *Eudesia cardium*,

etc. (*e*) Callovian, with *Reineckia anceps*, *Stepheoceras* sp., *Phylloceras* sp., *Modiola solenoides*, *Gervillia aviculoides*, and very abundant *Rhynchonella Orbignyi*.

Beds of lithographic limestone (*f*) form a horizon easy of recognition, and are best developed in Gebel Hamaiyir. They have furnished some sections of *Belemnites* and a cast of *Quenstedticeras*. At the same level have been found a fragment of *Pachyceras*, large *Terebratulæ*, related to *T. Lamberti* and *T. suprajurensis*, as also *Zeilleria Parandieri*. These beds were regarded as representing the Upper Callovian and Oxfordian, perhaps even the Upper Jurassic. (*g*) This latter horizon seemed to be indicated by a fragment of a *Lytoceras*, having the characters of *L. Liebigi* var. *strambergensis*.

The Jurassic strata are thus developed on a large scale in this portion of Egypt, as are also the Lower Cretaceous beds, which overlie them in great thickness.

(*h*) The Lower Cretaceous strata were noted as represented by limestone containing grains of quartz or small ferruginous oolites. These were stated to have yielded *Knemiceras syriacum*, *Protocardia hillana*, *Eoradiolites Rousseli*, *Neithea quinquecostata*; a lower stratum seemed particularly rich in species of large Trigonias, *Tr.* like *crenulata* and *Tr.* like *sinuata*. These beds were regarded as the extension of the well-known Lower Cretaceous formations of the Lebanon, where they represent the "Vraconnian". Like the Jurassic, these had never yet been recorded, either in South Palestine or in Egypt. It is of interest to note, however, that M. C. Barthoux has also noted the *Knemiceras* beds at the foot of Gebel Shabrawet, one of the hills near Faied Station (Ismailia-Suez line) to the west of the Suez Canal.

(*i*) The highest beds of the series studied are yellowish, very fossiliferous limestones of typically Cenomanian age, with such characteristic fossils as *Neolobites Vibrayei*, *Exogyra flabellata*, and *Orbitolina concava*, race *minor*.

The larger work, "Les Terrains Secondaires dans le Massif du Moghara à l'est de l'isthme de Suez d'après les explorations de M. Couyat-Barthoux et M. H. Douvillé," deals with the palæontology of the area in greater detail, full descriptions being given of the principal *Cephalopoda*, *Gasteropoda*, *Lamellibranchiata*, *Brachiopoda*, and *Foraminifera* in the various formations.

The results differ in no important respect from those recorded in the first paper; the *Knemiceras* is, however, *K. Uhligi* Choffat, and not the closely related *K. syriacum*.

The war brought further study of North Sinai to a conclusion for some years, and only in the season of 1918–19 did M. Fourtau (acting in his capacity of palæontologist to the Geological Survey of Egypt) commence a detailed examination of this portion of Northern Sinai, extending his researches eastward to embrace the massif of Gebel Helal in 1919–20. In the latter period Messrs. Moon and Sadek examined an area of some 8,000 square kilometres in North-

Western Sinai in connexion with the petroleum research programme of the Egyptian Government, the object being to obtain the fullest details possible as regards the stratigraphy and structure of the region, with the question of the indications of petroleum in the forefront of the research. The writer had hoped to have personally examined some interesting portions of this area, but other field duties intervened. Nevertheless, he was enabled during the early days of May, 1920, to visit that portion of the region in which these newly discovered formations are best developed. M. Fourtau kindly prepared a programme which would enable the writer, with Messrs. Moon and Sadek, to obtain a broad view of the northern series of ridges (Gebels Risan El Aneiza, Mistan, Lagama, the main Maghara range), the party crossing Sinai from El Arish to Ismailia.

The characters of the Risan El Aneiza massif were practically unknown, and the party subdivided itself during the course of the examination. On reuniting in the evening it was found that interesting results had been obtained. Fourtau, following the southern boundary of the hills, had found Jurassic strata in Ras Jehan, while Sadek discovered beds of the same age in the centre of the range, forming part of a faulted-in region to the east of Ras El Ahmar. The writer was accompanied by Sheikh Shehata (brother of the head sheikh of the Terrabin), who, under M. Fourtau's influence, had become a keen and discriminating collector. While examining the Ras Ahmar ridge, the Sheikh was observed busily at work, just below the summit, and, on joining him, the writer had the satisfaction of meeting old Lower Greensand friends from the Isle of Wight, such as *Terebratula sella* and a typical species of *Gervillia*. Later in the day a ridge was visited which yielded a typical Aptian fauna, the research closing with the discovering of Albian (Gault), crowned by the Cenomanian known to be present here at the western end from Barthoux's researches. Thus it may now be stated that the Jurassic and Lower Cretaceous rocks are typically represented in this north-eastern extension of the Maghara fold.

The party subsequently studied the typical exposures of Jurassic and Lower Cretaceous age in the Mistan, Um Mafruth, Lagama, and Maghara hills, type examples of the whole series being examined in turn. Thus were seen the Ammonite beds of the Bajocian series bordering the east side of the Wadi Maghara, the *Bothryopneustes* beds, and those rich in *Rhynchonella Orbignyi* of the Callovian, the *Collyrites bicordata* bed of the Oxfordian and the representative of the Coral Rag. The Lower Cretaceous beds were most strikingly displayed in the neighbourhood of Bir Lagama, and from thence the succession traced over the pass of Aseifer into the valley to the north of Gebel Mandur. Species of *Puzosia* seemed the commonest cephalopoda at the base of the series, accompanied by numerous species of *Trigonia* (*T. Picteti* Coq. *T. pseudo-crenulata* Nötling). M. Douvillé considers that certain of the limestones with fine ferruginous oolites from Bir Lagama have furnished a certain number

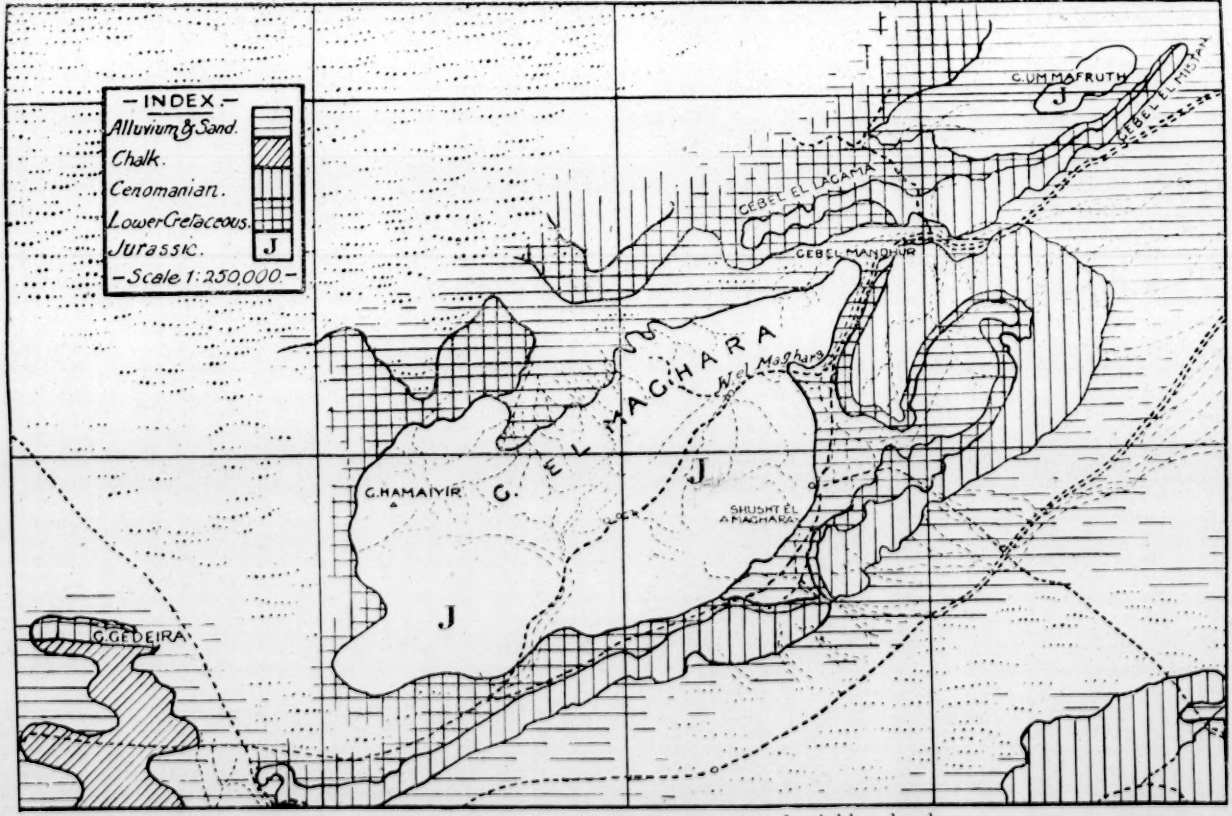

FIG. 2.—Geological map of the Maghara range and neighbourhood.

of cephalopods which are definitely of Barremian age (equivalent roughly to the Atherfield clay of the Lower Greensand in England and higher than the Neocomian). These include species of *Lytoceras*, *Costidiscus*, *Phylloceras*, *Desmoceras*, and *Crioceras*. The beds with which the writer became acquainted are, however, frankly Aptian (Lower Greensand), and as stated above contain species of *Puzosia* (*P. Matheroni* d'Orb, *P. Angladei*, Sayn), and of *Douvilleiceras* (*D. Meyendorfii* [Sinzow]). *Nautilus Lallieri* d'Orb. is also abundant.

A familiar British fossil found in these beds is *Terebratula sella* Sowerby.

As we mounted the pass, the series was followed in ascending succession by beds with an abundant *Echinoconus* and large Gasteropoda. A layer containing small ferruginous ammonites also attracted our attention. At a point where the pass steepens, and the path takes a sharp turn, are strata very rich in a beautiful variety of simple coral, *Trochocyathus* sp., etc. These beds M. Fourtau regards as typically Albian (Gault). At the summit of the pass are beds crowded with a foraminifer, *Orbitolina* cf. *concava* Lam. Finally, in the descent, the typical *Exogyra flabellata* was met with, indicating the presence of the Cenomanian formation already so familiar in other portions of Egypt and the Sinaitic peninsula.

M. Fourtau had kindly prepared the following notes for inclusion, these giving further details as to the character of the Jurassic strata in the Maghara area.

"The Lower and Middle Jurassic are very well represented at Maghara, but in consequence of the sedimentation having been continuous and there being both recurrence of faunas and of facies, it is difficult to determine the precise limits of the different horizons, Bajocian, Bathonian, Callovian, and Oxfordian.

"The Bajocian is poor in fossils, and its lower boundary with the grits difficult to define, so that one may regard the basal grits of the central dome of Maghara as possibly Liassic, though they might equally represent the earliest strata of the Inferior Oolite. The limestones are in general grey or blackish, and some of the beds are highly oolitic. The sea-urchin fauna is poor but characteristic. *Stomechinus bigranularis* Link, *Pygaster* cf. *semisulcatus* Ag., *Rhabdocidaris coploides* Ag. and at the top, *Holectypus depressus* Leske. The Brachiopods are represented by special forms of *Terebratula*, the *Parathyris* of Douvillé with *Zeilleria subbucculenta* Chapuis and Devalque. The Cephalopods are especially species of *Cœloceras*. As regards the Lamellibranchs, these are mostly rare, with the exception of a *Nucula* related to *N. tenuistriata* Sow.

"M. Douvillé places an Ammonite horizon in the Bajocian, following Barthoux in calling this the yellow limestones. These beds appear to us to have their place better at the base of the Bathonian, as they contain certain fossils more or less characteristic of that formation, such as *Eudesia cardium* Link, *Terebratula quillyensis* Bayle, and *Rhynchonella Orbignyi* Oppel. It is to be

observed that Douvillé (1918, page 34) noted that in this bed, which still contained Bajocian species, were already a number of species of Bathonian age.

"The Cephalopods are well preserved in these beds, the following being the most commonly represented: *Cœloceras Humphriesi* Sow., *Phylloceras disputabile* Zittel, and *Ph. mediterraneum* Neumayr, and the new types *Ermoceras mogharense* H. Douv. and *Thamboceras mirum* H. Douvillé. Above these strata follow limestones with *Terebratula quillyensis* and *Ostrea* (*Liogryphaea*) *costellata* d'Orb., then a succession of beds of grits and limestones, with *Rhynchonella Orbignyi*, *R. concinna* Sow., *R. obsoleta* Sow., and *Ostrea* (*Arctostrea*) *arita* Douvillé. The Bathonian must be considered as having preceded the oscillations of the grits. The echinid fauna is somewhat poor in known forms, except for the spines of *Plagiocidaris bathonica* Cotteau and *P. meandrina* Ag. The Mollusca have been described by Douvillé, it is to be noted that some of these reappear in the Callovian and even in the Oxfordian. The Callovian (if its base be placed at the level of the limestone with flint nodules above the last band of grit) is well represented by oolite and ferruginous limestones characterized by an abundance of small Atelostomatous sea-urchins of small size, closely related to *Pygurus*, but having their periproct in a marginal or supramarginal fossette, which brings them closer to the Cretaceous *Bothriopygus*, and which places them in the new genus *Bothryopneustes* R. Fourtau. Above follows a great thickness of blue-green marls broken by a band containing *Eudesia cardium* and *Pygurus* sp. nov.

"The limit between the Oxfordian and the Callovian is very difficult to determine, but certain beds are indisputably Oxfordian. One of these contains *Terebratula Lamberti* Douv., *Myoconcha Rathieri* d'Orb., *Ostrea* (*Arctostrea*) *amor* d'Orb., *Perisphinctes varicostatus* Buckland, *Aspidoceras Babeaui* d'Orb., *Ctenostreon proboscideum* Phillips, *Pecten fibrosus*, Phill., and *Rhabdocidaris capremontana* Desor; while above are limestones with *Collyrites bicordata* Desmoulins.

"Above these limestones commences what we regard as the Upper Jurassic, which is here represented by a stage including both Coral Rag and Kimmeridge Clay, a stage established in Portugal by Choffat, the Lusitanian. It commences with a thick mass of dolomitic limestones containing *Diplocidaris gigantea* Ag. and *Gymnocidaris* (*Hemicidaris*) *Agassizi* Roemer, fossils distinctly characteristic. The upper part corresponds to the "Glandarienkalk" of Syria, with *Plegiocidaris Choffati* de Loriol, *Pseudocidaris lusitanica* de Lor., and numerous crinoid stems belonging mainly to the genus *Millericrinus*. An interesting facies is presented by a dolomitic white limestone with mollusca changed to calcite, of which fine samples have been collected. The Portlandian and Tithonian are not represented."

The result of the operations of the Geological Survey and

Petroleum Research has thus been in the first place to re-study the great north-east-south-west fold of Maghara, etc., in which the Jurassic and Lower Cretaceous strata are best developed, and to prove the extension of these strata to the eastward in the Risan el Aneiza hills. Further, it has enabled the writers to become personally acquainted with the trend of the researches already undertaken, enabling them to attack the problems awaiting solution with enhanced knowledge.

There remains, however, a main question which will have occurred to most geologists and demands an answer. Why are these formations so strongly developed in the Maghara fold, yet so strikingly absent further south where Cenomanian strata of the most typical kind overlie a great thickness of Nubian Sandstone,[1] in which no trace of fossiliferous formations are to be met with?

We believe the answer to be that we are dealing with the phenomenon of *lateral variation* on the large scale. To the south of this region lay a great granitic-metamorphic continent. As its borders were approached, the strata became more and more sandy, further away from it marine formations were developed at an earlier age than further to the south. The theme dealt with by the writer in his paper on the "Secular Oscillations", read before the Geological Society, has expanded (W. F. Hume, "Secular Oscillation in Egypt during the Cretaceous and Eocene periods," *Q.J.G.S.*, vol. lxvii, 1911, pp. 118–48). We can no longer speak of the "Nubian Sandstone" as of Cretaceous age; it is a lithological condition which, beginning in late Carboniferous times both in Sinai and Eastern Egypt, was developed in Northern Sinai during the Trias and Lias, and also alternating with the fossiliferous Jurassic strata, as may be well seen in ascending the main Maghara crest. If these beds of known date were not present, it would be impossible to distinguish the sandstones from those regarded as of typically "Nubian Sandstone" character elsewhere.

The writer did not himself note so marked an alteration in the Lower Cretaceous formations. For Egypt itself he has already directed attention in the above paper to the breaking up of the Upper Cretaceous series by "Nubian" Sandstones, these lying very markedly between strata of Cenomanian and Turonian age; whereas south of that latitude both the fossiliferous Cenomanian and Turonian strata are represented by sandstone alone. We therefore scarcely expect, in pursuing the research further, to find fossiliferous Jurassic and Lower Cretaceous strata south of the fold in which they are at present known, but rather that elsewhere they will be "Nubian Sandstone". Much light has been thrown by Messrs. Moon and Sadek's work on the *structure* of the north-western portion of North Sinai, which embraces this area. M. Barthoux had already noted that the area was folded, constituting a series of

[1] See Ball on the "Geography and Geology of West Central Sinai", reviewed in GEOL. MAG., 1917, p. 80.

anticlines in which further to the south Cretaceous beds formed the crest, while the synclines were occupied by Eocene strata. These folds trended from north-east to south-west. It is now shown that these folds are markedly asymmetrical with their steep sides generally directed south-eastwards. The result is that the strata are not only thrown into regular anticlines, but dome structures are numerous. Naturally there is also much faulting, but not sufficient to obscure the fundamental folding. Perhaps the most striking feature is the existence of a remarkable narrow "steep zone", an extremely narrow fold which traverses the Maghara range, and has been traced over many kilometres. This will be described in detail by the writer's colleagues in the work now being prepared by them.

Finally, an indication may be given of the general theoretical conceptions which have appeared to arise from the most recent studies. The first is the conclusion that the folding which closed the Eocene period was north-eastward-south-westward in Sinai, changing to an east-west trend in Egypt itself, and perhaps again resuming the north-eastward direction in the Libyan Desert, for example, in Baharia Oasis. By this folding the deeper-seated granitic core was brought either near or to the surface, and may subsequently have acted as a buffer against which the already slightly folded sedimentary strata were further buckled into asymmetric folds under pressures continuing to act from the north-west.

It is noticeable that these pre-Miocene strata both in Sinai and Egypt show no trace of being affected by the series of movements which produced the "rift" effects. In the latter the north-westward trend of the strata is broadly developed between the greater fault lines (presumed to be continuous) which border the depression of which the Gulf of Suez occupies the centre. These faults have been proved with certainty at the base of the Red Sea Hills northward of lat. 26° N., and also at the feet of Gebel Ataka, near Suez, and Genefe, but a great deal of detailed work is still required before the continuous nature of the major fault can be established for the Egyptian side of the larger Gulf of Suez depression. On the Sinaitic side the major fault has been traced in much detail by Barron, Ball, Barthoux, and Moon and Sadek. It is hoped later to discuss the facts collected in relation to "Rift" theories.[1]

On Ammonites from Spitsbergen.

By L. F. Spath, D.Sc., F.G.S.

(*Concluded from p. 305.*)

There appears to be a good deal of variation in the Lower Triassic succession of the different parts of Spitsbergen, even between Ice Fjord and Bell Sound, at which latter *Gyronites nathorsti* J. Böhm

[1] This has taken place since this paper was handed in for publication, the writer opening a discussion on the subject at the Geological Society meeting of 8th June, 1921.

occurs in soft shales. The grey sandstones with a Lamellibranch fauna of Werfenian age from Axel Island,[1] again, represent quite a different facies.

The difficulties encountered in studying the Lower Triassic forms, and due, chiefly, to the conflicting evidence of the various matrixes, and to the fact that some of the best-preserved examples were found loose, are met with again in dealing with the Middle Triassic specimens.

Monophyllites sp. cf. *sphærophyllus*, Hauer sp.,
Ptychites cf. *trochlæformis*, Lindström sp.,
Ptychites? sp. cf. *tibetanus*, Mojsisovics,
? *Gymnotoceras* cf. *laqueatus*, Lindström sp.

are referable to the Middle Trias (Anisian), though they are only preserved as impressions in a black shale that apparently corresponds with the "Thin Paper Shales" (D_3) of Professor Gregory's section I. This shale is full of comminuted fragments of shells, and quite distinct from any other matrix, and it may be added that the two vertebral centra of *Aphaneramma rostrata* figured by Dr. A. Smith-Woodward have this matrix, whereas the skull is preserved in a hard nodular limestone reminiscent of the *Posidonomya* shales.[2]

Stolley [3] recorded a *Monophyllites* from the *Daonella* beds, and considered these to be of Ladinian age, and the equivalent of the Wengen beds. He found *Nathorstites*, which characterizes Upper Triassic beds on Bear Island and in British Columbia, only a little higher, and thus would draw the boundary-line between the Middle and Upper Trias just above the *Daonella* beds. The large specimen of *Monophyllites*, mentioned above, resembles *M. sphærophyllus* Hauer sp., but not *M. wengensis* Klipstein sp., and its association with *Ptychites* and *Gymnotoceras* suggests an Anisian age.[4]

The specimen of *Gymnotoceras*, unfortunately, does not show the inner whorls,[5] and has a different matrix from all the other examples of *Gymnotoceras* in the collection. These occur with *Lingula lindströmi* J. Böhm,[6] and the other Ammonites given in the list

[1] Wittenburg, "Üb. Werfen. Sch. v. Spitzbergen": *Bull. Acad. Imp. Sci. St. Pétersb.*, ser. VI, 1912, pp. 947–8.

[2] These specimens are from Sticky Keep, whereas the first three in the above list are from "Bluff, above entrance to Flower Valley, over nodule bed", (Escarpment Shales of Professor Gregory's Section II). The last (*Gymnotoceras*), which has a more slaty (worn) aspect, is from "Sassen-Bay".

[3] "Z. Kenntn. d. Arkt. Trias.": *N. Jb. f. Min.*, etc., vol. i, 1911, p. 117.

[4] Among 3,500 Bosnian Ammonites from the "*trinodosus*-zone", recently named by the writer, the genera *Ptychites* and *Monophyllites* were represented by 640 and 314 specimens respectively, and, besides Arcestids, the dominant element of the fauna.

[5] There is a certain resemblance in ornament to *Protrachyceras sverdrupi* Kittl ("Die Trias-Fossil. v. Heureka Sund": Report 2nd Norw. Arct. Exped. in the *Fram*, 1898–1902, No. 7, 1907, p. 39, pl. iii, fig. 9) also associated with a *Daonella* very similar to the Spitsbergen form.

[6] This author (loc. cit., p. 13) has a black, fine-grained limestone with this *Lingula* above the Lower Trias, and since the *Lingula* also occurs in slabs with *Daonella* he considers it of Ladinian (Middle Triassic) age. The form here

below, in a limestone which is very compact and black when fresh, but brownish, softer, and more flaggy when weathered, and which may correspond with the black, fine-grained limestone referred to by J. Böhm. The forms of these black limestones and calcareous flags (as distinguished from the above shales) are :—

Gymnotoceras laqueatum (Lindström), common.
,, *falcatum* (Mojsisovics).
,, *geminatum* (Mojsisovics), common.
Danubites ? sp.
Tropigastrites ? cf. *polygyratus* Smith.
Monophyllites cf. *spetsbergensis* (Öberg).[1]

The evidence, however, is by no means satisfactory; for very similar black limestones, weathering to various lighter colours, occur in nodules in the Lower Trias, and it should be mentioned that *Gymnotoceras falcatum* is labelled [by error ?]" Nodule-bed, Trident", and one specimen of *G.* cf. *laqueatum* comes from " E basement bed of Trident ". The latter has the matrix of some thirty specimens of *G. geminatum* (Mojsisovics), comparable with the two crushed specimens figured by Mojsisovics[2] from the black calcareous shales of the Hyperite Hat. It agrees with the " Calcareous Flags above nodules ", referred to above, characterized by a *Pseudomonotis*, but it may only represent a more weathered condition of the black crystalline limestone that contained *Lingula*, *Monophyllites*, and [doubtfully] *Gymnotoceras falcatum*. On the other hand, a similar *Pseudomonotis* occurs in the *Ptychites*-beds.[3]

Two quite indeterminable impressions of Ammonites are labelled " Phosphate Series, near Botanists' Camp, de Geer Valley Delta, Sassen Bay ", and probably came from one of the Oozy Mound Beds (E) of Professor Gregory's section I. Phosphatic shales are mentioned by Nathorst,[4] as occurring both in the Lower and, more frequently, in the Middle Trias (*Daonella* shales), but the more involute impression (unfortunately crushed quite flat) may even be a *Nathorstites*, and thus indicate a Carnian horizon.

The only fragment of an Ammonite, actually associated in the same slab with *Daonella*, unfortunately is indeterminable. On the

referred to *L. lindströmi*, like *Gymnotoceras falcatum* and *Monophyllites* cf. *spetsbergensis*, are preserved in a black limestone that is characterized by the brownish calcite, replacing the shells; but *Arctoceras* may be similarly preserved.

[1] This small form is characterized by three saddles, like Himalayan species of the group of *M. suessi*, figured by Diener (1895, pl. xxxi), but in shape more like *M. nara* Diener or *M. spetsbergensis* (Öberg).

[2] Loc. cit., 1886, p. 49, pl. ix, figs. 13, 14 only. Many examples of this form from " West of Fortress ", near Cape Staratshin, and from Trias Point, North Side of Van Keulen's Bay, Bell Sound, are in Mr. Reynolds's Collection.

[3] After seeing Professor Gregory's section I, the writer would put this *Gymnotoceras* fauna into D_1 (" Earthy Limestone ").

[4] " Beitr. z. Geol. d. Bären- Insel, Spitzb. und d. Kön. Karl Landes ": *Bull. Geol. Inst. Univ. Upsala*, vol. x, 1910–11, Nos. 19 and 20, p. 352.

Table of Triassic Succession.

Upper Trias?			? Upper Shales and Flags (unfossiliferous).			400 ft.	G.
Middle Trias (Virglorian).	Ladinian		Upper Nodule Bed.				F.
			? Oozy Mound Beds.	E_3: *Atractites* sp. E_2: *Daonella* (*Monoph.* cf. *wengensis*, *Ptychites*). E_1: ?		400 ft.	E.
	Anisian	Upper (*trinodosus*-zone)	3″ Limestone . . . . . D_4 Thin Paper Shale (*Ptychites*, *Monophyllites sphærophyllus*) . . . . . D_3	Escarpment Shales.		200 ft.	D.
		Lower?	Middle Nodule Bed . . . . . D_2 Earthy Limestone (*Gymnotoceras*) . D_1				
Lower Trias (Werfenian).	*Stephanites*-zone		Upper *Posidonomya* Shales (*Gymnotoceras*?). "Saurian" Bed (*Danubites*? *Gyronites*?). Lower *Posidonomya* Shales (*Arctoceras*, *Danubites*?).			600 ft.	C_2.
	Flemingites-zone		Lowest Nodule Bed (w. *Anasibirites*, *Keyserlingites*, *Prionites*, *Goniodiscus*, *Arctoceras*, gen. nov. (= "*Xenodiscus*", "*Danubites*"?), *Flemingites*?, etc.). Unfossiliferous Shales.			500 ft.	C_1. B.

other hand, Mr. Reynolds's Collection includes, besides *Monophyllites* cf. *wengensis* (which seems to confirm Stolley's evidence, referred to above), the following forms from the *Daonella* beds :—

Ptychites lundgreni, Mojsisovics.
,, sp. ind. (Mojs., p. 92, pl. xiii, fig. 2).
,, *concentricus*, Öberg sp.
? *Tropigastrites* sp.

Many of the *Ptychites* are crushed and resemble the oxycone *Nathorstites*, but the examples that have the suture-line preserved indicate the generic position of the forms.

II. Jurassic.

The list of Jurassic Ammonites includes the following forms :—

Amœboceras cf. *nathorsti* Lundgren sp.
,, cf. *kitchini* Salfeld sp.
,, cf. *alternans* (v. Buch) auct. sp.
Pictonia ? cf. *normandiana* Tornquist
,, sp. cf. *bigoti* Tornquist (= ? *A. triplicatus* Lindström, non Sowerby, pl. iii, fig. 2 only).
,, sp. ind.
"*Perisphinctes*" (? *Pictonia*) sp. ind.[1]
Rasenia cf. *uralensis* d'Orbigny sp.
,, sp. n.? cf. *trimera* (Oppel) de Loriol sp.
,, ? cf. *swindonensis* Pavlow sp.
Virgatites cf. *polygyratus* (Trautschold) Pavlow sp.
,, cf. *scythicus* Vischniakoff sp.
,, cf. *nikitini* Michalski sp.
Craspedites sp. cf. *nodiger* (Eichwald) Nikitin sp. e.p.
,, sp. nov.?
Piesetrobelus cf. *magnificus* (d'Orbigny) Pavlow.

They were collected at Cape Staratshin, Ice Fjord, and at "Fastness Camp", east of that Cape, with the exception of one slab of black shale, full of large examples of *Amœboceras* cf. *nathorsti*,[2] that is labelled "Sassen Downs". All the other specimens of this form, from Cape Staratshin, are preserved in a softer, micaceous, black shale, which also contains *A.* cf. *kitchini* [3]; some more evolute examples seem to be closer to the forms described as *A.*

[1] A number of specimens of comparable Perisphinctids and *Virgatites* from Cape Delta, Sassen Bay, are in the Reynolds Collection.

[2] Lundgren, "Jura und Trias Fossil., etc.": *Bihang till K. Svenska Vet. Akad. Handl.*, vol. viii, No. 12, 1883, p. 6, pl. i, figs. 1, 2. Most of the examples, representing impressions of large individuals, appear to be coarser than Lundgren's figures, and may belong to the form recorded as *Cardioceras* n.sp. from black, carbonaceous shales of the King Charles's Isles by Pompeckj ("Marines Mesozoic. v. König-Karls-Land": *Öfversigt af k. Vet. Ak. Förh.*, 1899, No. 5, p. 458).

[3] Very close to examples in the British Museum, identified by Dr. Salfeld, from a very similar carbonaceous shale of Culgower and Cromarty, Scotland, also containing *Rasenia*.

alternans from apparently contemporaneous beds of Greenland,[1] and, on account of the single costation, also to the form referred to *Amœboceras* cf. *bauhini* (Oppel), by Ilovaïsky, from his highest bed D_4.[2] Lahusen[3] refers to this "Schwarzer Brandschiefer" of Spitsbergen, with *A. nathorsti*,[4] as containing *Aucella radiata* and *Aucella bronni*, but though some of the slabs of this micaceous shale with *Amœboceras* contain isolated *Aucella* of the type of *A. spitsbergensis* and *A. reticulata* Lundgren, these *Aucella* are more plentiful in other examples of this shale, not associated with Ammonites.

In the finer-grained, non-micaceous shales that Lindström[5] and Lundgren[6] mention as containing *A. triplicatus*[7] and *Aucella*, shells of the latter genus also are very abundant, but the *Aucella mosquensis* probably was misquoted for a plicate variety of *A. pallasi*. This occurs together with *A. bronni* Rouiller, so that a Kimmeridgian age (zone of *Aucella bronni* of Lahusen) is most probable. Pompeckj,[8] however, records *Perisphinctes* cf. *triplicatus* (Lindström), together with *Aulacostephanus* (and corresponding *Aucella*), thus suggesting a higher horizon in the Kimmeridgian (Hoplitenschichten of Lahusen) than is indicated by the forms of *Pictonia* which belong to the lower *alternans* beds. The Ammonite impressions in this black shale, characterized by its weathering to various colours, unfortunately are badly preserved; there is great resemblance to the forms of *Pictonia* quoted above, but also to Perisphinctids of the *achilles–decipiens* group. The primary ribs distinguish the forms from *Rasenia*, e.g. *R. triplicata* (Sow. in Damon),[9] or the still higher *Virgatites*. On the other hand, one example agrees very well with *V. polygyratus* (Trautschold) in Pavlow,[10] so that it appears probable that a number of horizons

[1] J. P. J. Ravn, "On Jurass. and Cret. Foss. from N.E. Greenland": *Mus. Min. Géol. Univ. Copenhague, Comm. Paléont.*, No. 10, 1911, p. 486, pl. xxxvi, figs. 1–3.

[2] "L'Oxf. et le Séquan. d. Gouv. de Moscou et de Riasan": *Bull. Soc. Imp. Nat. Moscou*, N.S., vol. xvii (1903), 1904, p. 273, pl. xi, fig. 2.

[3] "Üb. d. Russ. Aucellen": *Mém. Com. Géol. St. Pétersb.*, vol. viii, No. 1, 1888, p. 44.

[4] Additional examples of *A. nathorsti* in the Reynolds Collection come from the south side of Van Keulen's Bay, Bell Sound, and from Green Harbour (south-west).

[5] "Om Trias och Jura- Först. fr. Spetsbergen": K. *Svenska Vet.-Akad. Handl.*, vol. vi, No. 6, 1866, pp. 10, 19.

[6] Loc. cit., 1883, p. 3.

[7] Sowerby's *A. triplicatus* (xcii, 2) is a *Rasenia*; *A. triplex* (ccxciii, 4) and *A. trifidus* (ccxcii) are Corallian Perisphinctids.

[8] In Nathorst, "Eine vorläuf. Mitt. v. Prof. J. F. Pompeckj üb. d. Altersfrage d. Juraablag. Spitzbergens": *Geol. Fören. Förh.*, vol. xxxii, Heft 6, Nov. 1910, p. 1503 (table).

[9] *Supplement to the Geology of Weymouth, etc.*, new ed., 1888, pl. xiii, fig. 3.

[10] *Études*, etc., i, 1889, p. 60, pl. iii, fig. 3*a* only. Trautschold's original (*A. polygyratus* Rein., "Z. Fauna d. Russ. Jura": Moskau, 1866, p. 19, pl. iii, fig. 4) is quite different.

of the Kimmeridgian and Portlandian may be represented, and that the so-called *A. triplicatus* includes a variety of forms.

The specimen referred to *Virgatites* cf. *scythicus*, Vischniakoff sp.,[1] is very close to, but more evolute than, Michalski's figure 2[2] of that species, and has the same fine, dichotomous costation. It is preserved in a slightly different shale, without *Aucella*, that resembles the matrix both of *Rasenia* and of that of the gigantic *Virgatites* cf. *nikitini*, which latter includes crushed *Aucella*. This specimen of *Virgatites*, 240 mm. in diameter (with two fragmentary specimens of a closely comparable form), superficially resembles the large Ammonite figured by Nikitin[3] as *Perisphinctes martelli* Oppel, but which Siemiradzki[4] considers to be an intermediate form between *P. martelli* and *P. orientalis* Siemiradzki. Large "*Perisphinctes*" of the group of *P. wartæ* Bukowski are recorded from beds that contain an early (Corallian) development of *Amæboceras* ("zone of *P. wartæ* and *Cardioceras alternans*" in Salfeld[5]), but the crushed example here discussed, with its *Aucella* (not radially marked), is a *Virgatites*,[6] and not a Corallian "*Perisphinctes*", that is to say, it comes from above, not from below, the micaceous shales with *Amæboceras* cf. *nathorsti*.

The specimens of *Rasenia* apparently came out of nodules in the black shales, and since Salfeld[7] records *Amæboceras kitchini* from the zone of *Rasenia cymodoce*, it is possible that they belong to the same horizon as the micaceous shales with *Amæboceras* cf. *nathorsti*. The specimens are not very well preserved, and there does not seem to be a very close resemblance to the common Market Rasen species (*R. evoluta*, *involuta*, etc.). The example compared with de Loriol's figure of *R. trimera*,[8] with a diameter of about 150 mm., exceeds in size the form of *Rasenia* figured by Quenstedt[9] as *A.* cf. *trifurcatus* Zieten.

[1] A comparable specimen in the Reynolds Collection comes from Ulla Berg, North Side of Van Keulen's Bay, Bell Sound.

[2] "D. Amm. d. Unt. Wolga-Stufe": *Mém. Com. Géol. St. Pét.*, vol. viii, No. 2, 1890, p. 121, pl. vii, fig. 2 only.

[3] "Allg. Geol. Karte v. Russland, Blatt 71, Kostroma": *Mém. Com. Géol.*, vol. ii, No. 1, 1885, p. 125, pl. iii, fig. 14.

[4] "Monogr. Beschreib. d. Amm. Gattung *Perisphinctes*": *Palæontographica*, vol. xlv, pts. iv, v, 1898–9, p. 269.

[5] "Die Gliederung d. Ob. Jura in N.W. Europa, etc.": *N. Jb. f. Min.*, etc., Beil. Bd. 37, 1914, p. 129, and table i.

[6] There is very good agreement with *Per. nikitini* Michalski (loc. cit., p. 232, pl. xiii, fig. 1), but the much larger outer whorl has the aspect of that of such gigantic forms as *Virgatites virgatus* (in Michalski, loc. cit., pl. iii, fig. 1) or of "*Perisphinctes*" *losseni* Neumayr & Uhlig ("Ub. Ammonitid. a. d. Hilsbild. Norddeutschl.": *Palæontographica*, vol. xxvii, pts. iii–vi, 1881, p. 144, pl. xviii). The inner whorls characterize the latter as probably a *Polyptychites*, so that the resemblance of the outer whorl is only superficial.

[7] Loc. cit., 1914, p. 129; also "Certain Upper Jurassic Strata of England": *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, p. 423.

[8] "Mon. Pal. z. à *A. tenuilabatus*, etc.": *Mem. Soc. Pal. Suisse*, vol. iii, 1876, p. 86, pl. xiii, fig. 13.

[9] *Amm. d. Schwäb. Jura*, 1888, p. 998, pl. cxii, fig. 3.

The two forms of *Craspedites* are characterized by their compressed and almost smooth inner whorls, with a deep and comparatively small umbilicus. The outer whorl of the first example agrees very well with Nikitin's fig. 20,[1] and is just a little coarser in ornament, though not nearly so nodate as fig. 19, which, however, it equals in size. The other example resembles in its more sharply defined costation (of the outer whorl only) certain forms of *Craspedites* from the Rjasan horizon,[2] and the Neocomian *Tollia*, but it is quite different from the finely costate Valanginian forms from Northern Germany in the British Museum. The inner whorls of the type of those of a compressed *C. okensis* d'Orbigny sp.[3] show this second form to belong to the Purbeckian *Craspedites*.[4]

Some fragments of belemnites, apparently from the Upper Jurassic beds of Cape Staratshin, seem to be referable to *Piesetrobelus magnificus* (d'Orbigny) in Pavlow.[5]

III. Cretaceous.

The only Ammonite in the collections from Green Harbour, a fairly well-preserved specimen of

Polyptychites sp. nov. cf. *suessi* Koenen,

indicates the presence of the lowest Cretaceous or Valanginian. The form differs from Koenen's type [6] in having a deeper and more funnel-like umbilicus, and in the weakening of the costation on the outer whorl. *P. spharicus* Koenen [7] and *P. stubendorffi* (Schmidt) Pavlow [8] also are somewhat similar. The loss of the costation on the outer whorl is reminiscent of such forms as *P. variisculptus* Pavlow [9] and *P.* sp. (*Olcostephanus* cf. *triptychiformis* Nikitin et *syzranicus*

[1] Loc. cit., 1885, p. 133, pl. v, fig. 20.

[2] E.g. *C.* [" *Olcosteph.*"] *bidevexus* Bogoslowsky, " D. Rjasan Horizont, seine Fauna, etc." : *Mat. z. Geol. Russl.*, vol. xviii, 1897, p. 56, pl. iii, figs. 3, 4.

[3] In Murchison, Verneuil, & Keyserling, *Géol. d. l. Russ. d'Europe*, etc., vol. ii, pt. iii, Pal., 1845, p. 439, pl. xxxiv, figs. 13–17. Tullberg (" Üb. Verstein. a. d. Aucellen-Schichten Novaja-Semljas " : *Bihang till K. Svenska Vet.-Akad Handl.*, vol. vi, 1881, No. 3, p. 7) records *Craspedites okensis* from Novaja-Zemlya, where *Amœboceras* also is found

[4] Salfeld (" Monogr. d. Gattg. *Ringsteadia* " : *Palæontographica*, vol. lxii, pl. ii, 1917, pp. 73–4) points out that certain *Involuticeras* of a much lower horizon have been confused with *Craspedites* (e.g. by Burckhardt, 1906), but the boreal forms here described have no resemblance to the Southern *Involuticeras*. Their poor state of preservation, unfortunately, prevents exact comparison with the numerous similar *Craspedites* of the *subditus–plicomphalus* group in the Blake Collection.

[5] *Argiles de Speeton*, 1892, p. 44, pl. v (ii), figs. 1, 2 ; also Sibir. Sept., loc. cit., 1913, p. 16, pl. ii, fig. 4.

[6] " Die *Polyptychites*-Arten d. Unt. Valangin." : *Abh. k. Preuss. Geol. Landesanst.*, N.F., Heft 59, 1909, p. 76, Atlas pl. xii, figs. 2, 3.

[7] " Die Ammonitid. d Nordd. Neoc." : *Abh. k. Preuss. Geol. Landesanst.*, N.F., vol. xxiv, 1902, p. 122, pl. iv, fig. 1 only. This, however, belongs to a higher zone and the suture-line is different.

[8] " Les Céph. d. Jura et du Crét. Inf. d. l. Sibir. Sept." : *Res. Scient. d l'Exp. Pol. Russ.*, 1901–3, Sect. C ; " Geol. & Pal., Livr. 4 " : *Mém. Acad. Imp. Sci. St. Pét.*, ser. VIII, vol. xxi, No. 4, p. 29, pl. vi, fig. 1.

[9] Ib., p. 19, pl. iii, fig. 2.

Pavlow) in Bogoslowsky,[1] both of which, however, have a wider and less funnel-like umbilicus. The suture-line is characterized by four saddles between the siphonal line and the umbilical tubercle, the third of which (second lateral) is deeply bifid.

The matrix of this specimen is a very dark and hard limestone; but a fragmentary specimen preserved in a less calcareous rock, that partly is a true clay-ironstone, probably belongs to beds of the same age. This was collected at Fastness Camp, Cape Staratshin, and on account of its association with the similarly preserved *Rasenia*, *Virgatites*, etc., the writer at first was inclined to put it into *Gravesia*, though the umbilical tubercles are not rounded, but sharp and comma-shaped, or into *Cadoceras*. The specimen, unfortunately, is fragmentary, and shows no trace of the suture-line, representing probably the body-chamber of a large form (D = 150 mm.), with the inner whorls poorly preserved in crystalline calcite.

The specimen may be compared with

Euryptychites cf. *gravesiformis* Pavlow,

especially the smooth form figured on pl. xi, figs. 2*c*, 3,[2] but it has a less depressed whorl section and thus a more rounded periphery. *Polyptychites tschekanovskii* Pavlow,[3] on the other hand, is too compressed and too involute, and still costate at a large diameter. *P. senilis* Koenen[4] and *P. solidus* Koenen[5] show a somewhat similar smooth and fat outer whorl.

To judge by the two specimens mentioned, it would appear as though the Valanginian deposits were closely connected with the Purbeckian and Portlandian beds below, yielding *Craspedites* and *Virgatites*. The matrix of the specimens of *Euryptychites* and *Craspedites* is very similar and agrees with that of numerous *Aucella* of the group of *A. terebratuloides*. Other examples that appear to include the higher *A. keyserlingi* are "phosphatic".

On the other hand, the *Ditrupa* sandstones, with *Crioceras*, that may be as high as Aptian,[6] clearly belong to another set of deposits. Stolley records clays, with concretions, and a very doubtful fragment of a *Garnieria* [= a Valanginian *Platylenticeras* ?] below a flaggy, grey sandstone of the Flysch facies, with interbedded clayey seams; further, a very doubtful *Polyptychites* or *Simbirskites* from the *Ditrupa* sandstones. A change of facies between Cape Staratshin and Green Harbour on the one hand, and Advent Bay on the other, is, of course, possible, but the writer would refer all the Ammonites

[1] "Mat. z. Kenntn. d. Untercret. Amm. Fauna v. Centr. und N. Russl.": *Mém. Com. Géol.*, N.S., Livr. 2, 1902, p. 140, pl. xvii, fig. 1.

[2] Loc. cit. (Sibir. Sept.), 1913, p. 37.

[3] Ib., p. 34, pl. viii.

[4] Loc. cit., 1909, p. 50, pl. xx, figs. 1, 5.

[5] Ib., p. 52, pl. xxii, figs. 1, 2.

[6] Stolley, "Üb. d. Kreideform. und ihre Fossil. auf Spitzbergen": *K. Svenska Vet.-Akad. Handl.*, vol. xlvii, No. 11, 1912, pp. 10–12.

in the collection that come from Bunting Bluff, Advent Bay, to the Albian.[1] The specimens are extremely poorly preserved in a purple or brown, ferruginous sandstone, and associated with *Panopæa* of the type of *P. plicata*, a small smooth *Pecten*, etc. They are referred to :—

Sonneratia ? sp. cf. "*Hoplites*" *jachromensis* (Nikitin).[2]
,, ? sp. cf. *latisulcata*, Sinzow.[3]
,, ? (*Hoplites*?) spp. ind.
Cleoniceras ? cf. *bicurvatoides* Sinzow sp.[4]

Pompeckj[5] recorded "*Virgatites*-like" Ammonites, resembling the Albian *Hoplites jachromensis* Nikitin, from a sandstone (*Dentalium* beds) of the Fyrkanten Berg ; but on account of the bad state of preservation of the fossils he could not assign a more definite horizon to them than "Portlandian (Lower Cretaceous)", with possibly the Albian included. It is matter for regret that the species here recorded are equally unsatisfactory, but they certainly seem to be nearer to Albian forms than to those of any other stage. It may also be added that they had already been referred to "*Hoplites*" in the field.

A comparatively well-preserved but small fragment of the body-chamber of an Ammonite similar to the first form recorded in the above list was collected by Mr. W. J. Reynolds this summer (1920) at Whale's Head. It is comparable with the form figured by Bogoslowsky from the "*dentatus* zone" of the Albian, but not identical with Sinzow's *Sonneratia jachromensis*.[6]

Stolley[7] thinks it possible that the hundreds of feet of sandstones, between the *Ditrupa* (= "*Dentalium*") beds, with *Crioceras* and the Tertiary strata, may include the Gault and the whole of the Upper Cretaceous; but the apparent gaps and certain doubtful plant-bearing beds make a re-examination of the whole of the Cretaceous succession very desirable.

In conclusion, the writer would like to express his indebtedness to those who have kindly assisted him in the examination of this fauna, namely, to Dr. A. Smith Woodward, F.R.S., and to Dr. C. W. Andrews, F.R.S., for their help in connexion with the fish and amphibian remains, to Mr. W. J. Reynolds for his ready assistance with stratigraphical information, and to Professor J. W. Gregory, F.R.S., for his continued help and interest in the preparation of this paper.

[1] The writer is unable to assign these specimens to any bed of Professor Gregory's succession.
[2] In Bogoslowsky, loc. cit., 1902, p. 128, pl. vi, fig. 4.
[3] "Beitr. z. Kenntn. d. südruss. Apt. und Alb." : *Verh. Russ. Kais. Min. Ges. zu St. Pet.*, ser. II, vol. xlvii, 1909, p. 31, pl. ii, figs. 27–9.
[4] Ib., p. 29, pl. ii, figs. 7–18.
[5] In Nathorst, loc. cit., p. 1500.
[6] "Untersuch. Ammonit. Unt. Gault Mangyschlaks und Kaukasus" : *Verh. Russ. Kais. Min. Ges.*, ser. II, vol. xlv, 1907, p. 473, pl. iii, figs. 9–13.
[7] Loc. cit., p. 12.

The Use of Graphs in Palaeontology

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GRAPHIC methods for the comparative study of numerous observations and facts have long been in use in the exact sciences. They have also been used to some extent in those branches of the descriptive sciences which deal more particularly with the problems of heredity and variation. The purpose of the present paper is to sketch in outline a way in which they may be used in the morphological and systematic study of fossils.

It is necessary at the outset to recall the precise nature of the material with which the palæontologist has to deal. In studying living organisms it is customary to think in terms of species, genera, and the like, either individually or distributed in space. This is the practice also in the study of fossils, but in this case the element of time must also be taken into account. The palæontologist consequently pictures species as merely members of a long, probably continuous, series, which he calls a line of descent or a lineage. He is fortunate indeed if his collection of specimens is so complete that he is able to reconstruct such a lineage in all its stages. Even when he has done this with the best fossil material available, the fact remains that his results are based upon incomplete evidence; for all the softer parts of the animal—the nervous system, musculature, vascular system—perished long ago. Even the hard parts which are preserved for his use are frequently fragmentary, and consist merely of a bone, a spine, a thecal plate, or a spicule. To these he may give generic and specific names, which have a use and value; but it must not be forgotten that such fragments cannot constitute a species, they are only a few of the many structures which together make up a species. Names or no names, the palæontologist is usually concerned with isolated or small groups of structural elements, or units, and never with the complete animal.

All this may seem trite; but it is necessary to remind ourselves occasionally that our so-called lineages are usually little more than studies in series of changes undergone by a small proportion of the structural units which make up the living organism, and that absolute phylogeny is an almost unattainable ideal. The greater the number of units studied, the closer will be the approach to a true conception of the lineage, or line of descent, of the species, and therefore to the realization of the ideal.

The ever-accumulating fossil material makes it increasingly difficult to keep in mind all the peculiarities exhibited by each structure in all the genera, species, and varieties with which the investigator has to deal. For this and other reasons it seems desirable to seek for some method of expressing the morphological features of several types concisely, and in such a way that their evolutionary significance may be easily grasped. In setting forth

suggestions for such a method it will be necessary, first of all, to give some account of the principles which underlie a suitable method. This will be followed by several examples illustrating the application of the method. Finally, sundry thoughts suggested by these examples will be discussed.

Structural Elements and Flow Lines of Change.

No one can study the anatomy and development of several types of allied organisms, living or extinct, without realizing that they consist of various parts, each of which, whilst it is correlated with the others, undergoes changes and modifications that are peculiarly its own. Such parts may be referred to as structural elements or units. In a broad sense they may be anything from a single cell to a complete organism, from a cell that becomes a muscle fibre, to a tadpole that becomes a frog. In the narrower sense in which the term is used in this paper they may include any relatively simple part, as a digit; or relatively complex part, as the whole limb of a vertebrate; a single segment, or the whole glabella or pygidium of a trilobite.

The term organ is not synonymous with structural unit. An organ such as the eye, or fin, may be treated as one structural unit, or as consisting of several units, according to the object of the particular inquiry.

When a structural unit is followed through the life-history of an organism, it is seen to undergo a series of changes, which is usually described as its course of development. If, on the other hand, it be examined in a number of more or less closely allied genera and species, which are either contemporaneous or follow one another in time, it is found to exhibit a series of conditions often strikingly like those which are seen at different stages in development.

By such developmental and comparative studies it is possible to reconstruct the series of changes to which any given unit is subject. The problem is analogous to that of the stratigraphical geologist seeking to work out the sequence of the rocks. A complete and unbroken sequence in one exposure is as rare as a similarly perfect lineage in a museum. He must therefore attain his end by piecing together the information obtained from several exposures. So, likewise, the palæontologist may discover the sequence of changes experienced by individual structural units by piecing together fragments of information obtained by the comparison of allied forms, and from portions of imperfectly known lines of descent. An illustration will perhaps make this clearer.

A comparison of a large number of palæozoic echinoids[1] reveals the fact that the ambulacral plates assume various shapes. When these are placed side by side they can be arranged to form a series of which several steps are shown in Fig. 1, I–III. A further series can be recognized which follows the lines of an increase in the number

[1] R. T. Jackson, *Mem. Bost. Soc. Nat. Hist.*, 1912.

of plates in a transverse row (Fig. 1, IV–VII). Is this seriation merely due to the ingenuity of the human mind, or does it represent a series of changes which the plates may actually undergo in evolution? The following strands of evidence taken together create a presumption that the latter is the true explanation.

(1) While plates like I occur as early as the Ordovician, others do not become manifest until a later date. Presumably, therefore, this is the most primitive condition.

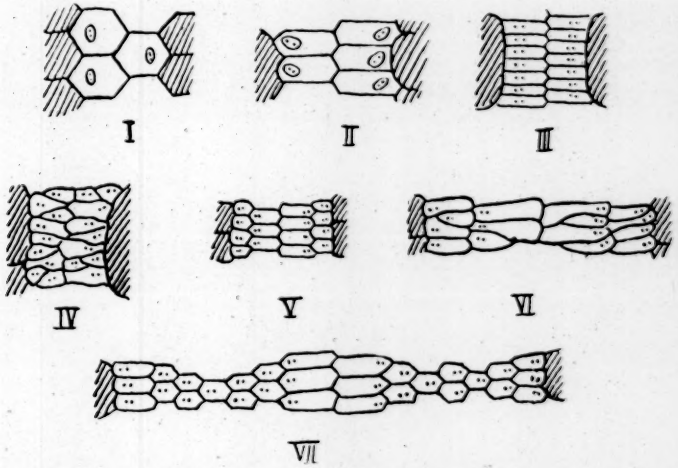

FIG. 1.—The ambulacral plates of various Palæozoic echinoids: I, *Bothriocidaris*; II, *Hyattechinus*: III, *Lepidocentrus*; IV, *Lepidocidaris*; V, *Lovenechinus*; VI, *Oligoporus*; VII, *Lepidesthes* (after Jackson).

(2) Plates like those shown in III, for example, are not confined to forms which are closely allied, but also occur in forms which are distantly related. They are, therefore, not peculiar to any one particular line of descent.

(3) Among closely related forms some may show shape II, some shape III, and others such conditions as IV–VI, etc. Evidently a number of steps in the series may occur within the narrow limits of a few closely allied lines of descent.

(4) Some of the modern echinoids exhibit in early development plates like I, which at later stages become like III.

(5) Two or more shapes of plate, and any number from two to twenty, may be present in different parts of an ambulacrum of the same individual.

These last two facts indicate that some or all of these shapes may occur in the same line of descent. In a similar way the direction of change in structural units of any group of organisms may be traced.[1]

Such structural units, and the directions of change they follow,

[1] See Osborn, *Amer. Naturalist*, 1917, p. 449 et seq. For full discussion of separability of units of organic structure.

provide the framework both for verbal description and for graphic representation.

In any series of changes thus elucidated the range is limited in extent and lies between two extremes, which may be usually ascertained for any group of organisms. Thus the number of plates in a transverse row of ambulacrum is not known to be less than two or more than twenty. The extreme range of shape, moreover, does not normally extend beyond the limits depicted in Fig. 1, I and III. There may be special groups, such as irregular echinoids, in which the modification of these plates may be carried to greater extremes. But even among them the range is limited. This is true also for the structural units in any group of organisms, as well for the number of toes or of teeth or the pattern of the dental crown in mammals, as for the degree of coiling or complexity of suture line in ammonites. In all the great orders, as in the Echinoids, there are special groups in which the range for any one structure may be excessive, as, for example, the teeth of the Proboscidea, and the suture line of the Pinacoceratidæ. But even in these cases the range will be found to have its limits.

Further, it must be remembered that, within the bounds of any group of allied forms, the number of directions of change for any particular structural unit is likewise limited. Numerical characters can only increase or decrease in number, coiling of a shell can only be in a plane or in a cork-screw spiral up to a certain height. This is merely putting the case for orthogenesis and rectigradation from the standpoint of individual structures, rather than from the standpoint of the organism as a whole. What is a variation in an organism is often merely another step in the serial change of a structural unit.

Hitherto the term structural unit has been used as though it always stood for something that was quite clear and precise. This, however, is not the case. Serial change may take place on a basis that is too vague and ill-defined for description as a structural unit. The ornamentation of an ammonite shell exhibits quite well-defined series of changes—but what is the structural unit which changes? Examples of this kind serve to emphasize the importance of thinking less statically and more dynamically, less in terms of structures that are present or absent, and more in terms of characters that are changing.

Morphological Graphs and their Interpretation.

In order to explain the use of the principles just enunciated for the purposes of graphical representation, the unit series of changes recognizable in any type of organism may be represented by the capital letters, *A*, *B*, *C*, etc. Thus, in the illustration already taken from Palæozoic echinoids, the series of changes shown in Fig. 1, I–III, may be called *A*. The series showing increase in numbers of plates in a transverse row may be called *B*, and so on.

The steps in each series may be taken as they stand, or they may

be expressed as a percentage of the total possible range. In the latter case the extremes of each series are taken as 0 per cent and 100 per cent respectively. The former method will be illustrated later, only the latter will be used here.

These two items, the series as a whole and the percentage of change within each series, are placed along the co-ordinate (Fig. 2).

If in a specimen *a*, one of a group of organisms which is being studied, series *A* has advanced to 40 per cent of the possible range, *B* to 20 per cent, *C* to 60 per cent, *D* to 20 per cent, and *E* to 25 per cent, then the line *a* (Fig. 2, I) will represent the specimen *a*. Similarly the line β will represent the specimen β.

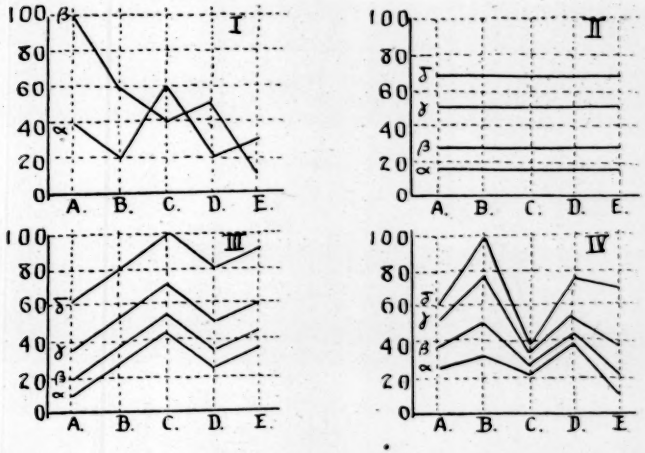

FIG. 2.—Diagrams illustrating the types of relationship that morphological graphs of organisms may have to one another.

Considering first a group of organisms belonging to the same lineage, two hypothetical cases may be taken :—

Case 1.—In this the rate of change is the same for all series. This implies that the series are intimately related with one another, so that the amount of change in one is, of necessity, accompanied by a proportional amount of change in each of the others. In this case the graphs, representing members of the lineage, will be parallel with one another. If each series started at zero, or at the same percentage level, then the graphs would be straight (Fig. 2, II). If each had its own starting point, the graphs would be crooked (Fig. 2, III).

Case 2.—In this the rate of change is different for the several series. This implies that the series are to some extent independent of one another, and not intimately correlated. The graphs, though they will not be parallel with one another, will develop out of, and will not cross one another (Fig. 2, IV).

Considering next a group of organisms which includes representatives of two or more lineages, only one case seems conceivable, viz. the one in which the rate of change is different for the several series. If the different series were so intimately correlated, that no change could take place in one without involving all the others in an equal amount of change, the members of one line of descent would be indistinguishable from those of another. As a matter of fact, even when there is striking homœomorphy, the members of the different lineages can still be sorted out from one another. This is because one lineage differs from another in the rate of change in one or more homologous structural units. In this case the graphs, representing several individual organisms, will not develop out of one another; on the contrary, they will cross one another (Fig. 2, I).

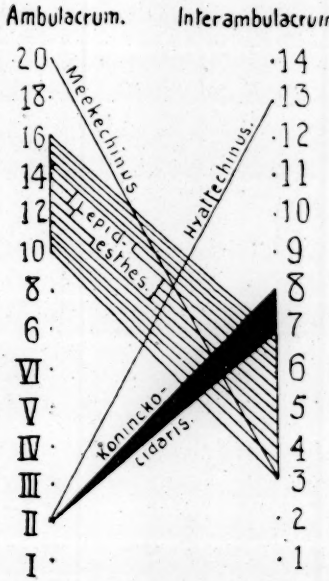

FIG. 3.—Graphic representation of some of the differences existing between several genera of Palæozoic echinoids. The Roman numerals I–VI stand for the drawings having the same numbers in Fig. 1. The Arabic number 14 in the left column stands for drawing number VII.

EXAMPLES OF GRAPHICAL REPRESENTATION.

To illustrate the application of the methods just described to the graphical representation of fossils, four examples will now be taken. For the first the facts already drawn from the Palæozoic echinoids will be used. In this case the facts will be taken as they stand without reducing them to percentages of possible change. The other three will be taken from Carboniferous corals. In these the facts will consist mainly of measurements, and will be expressed in the form of percentages.

EXAMPLE I: THE PALÆOZOIC ECHINOIDS.

The systematist finds that the changes which take place in the ambulacral and interambulacral areas in Palæozoic echinoids are of great importance for his purpose. As already seen, in the ambulacral area the plates pass through changes of shape varying from that shown in I to that at III in Fig. 1. Further change consists in an increase in the number of plates in a transverse row from two up to twenty. The transition from two to four plates is shown at IV in Fig. 1. A similar transition from four to six plates is shown at VI in Fig. 1. It is thus that the increase referred to takes place. In the interambulacral area the number of plates in a transverse row varies from one up to fourteen. Other changes take place in Palæozoic echinoids, but these will serve to illustrate the way in which graphical methods may be used for visualizing evolutionary phenomena. By placing the figures representing these directions and series of changes in the two areas in two vertical columns (Fig. 3), they may be used for graphical purposes.

According to the systematists' description, the genus *Hyattechinus* has two plates in a transverse row in the ambulacrum, and these are of the shape depicted in Fig. 1, II. In the interambulacrum it has as many as thirteen plates in the transverse row near the greatest circumference. The line II–13 in Fig. 3, therefore, represents *Hyattechinus*. The shaded area 10/16–3/7 represents *Lepidesthes*. Similarly the graphs II–7/8, and 20–3, represent two other genera.

With such a diagram it is easy even for a beginner to grasp at a glance some of the vital principles by which, consciously or unconsciously, the systematists have been guided.

The mere possibility of making two such columns of symbols indicates that the direction of change is not indefinite, but definite.

The graphs show that the combination of stages in the development of structural units may be quite different in separate though related genera. Putting the same fact from another point of view, one genus differs from another in the combination, not only of structural units, but of stages in the development of those units.

Further, if it be assumed that some or all of the genera represented in Fig. 3 had a common ancestor, having as its graph I–1 or II–2, it is evident that the rate of change in homologous structures has not been the same during the evolution of these genera. Had it been the same, had the changes in the ambulacrum been of necessity accompanied by similar and equal changes in the interambulacrum, then the descendants of that ancestor would have been represented by a series of parallel graphs, e.g. III–3, VI–6, 14–11, and so on. Divergent lines of descent like those represented by II–13 and 20–3 would thus have been impossible. The fact that the graphs are not parallel, but tilt this way and that, and that such divergent lines of descent are recognizable, proves that the two series of changes are not immutably bound up the one with the other; and that the rate of change along different directions varies in one line of descent,

being practically stationary in one and progressing rapidly in another. (Cf. II–7/8 with II–13.) On the other hand, in different lines of descent, homologous structures may progress at different rates (cf. the ambulacral end of each of the four graphs).

Such considerations as these indicate that whilst a genus, species, or variety is characterized by a combination of structural elements at certain stages of development, a lineage, or line of descent, is characterized by a certain cluster of directions and rates of change.

(*To be continued.*)

A Hypothesis of Mountain Building

By A. J. Bull, M.Sc., F.Inst.P., F.G.S.

THE following paper is an attempt to contribute to the solution of the problem of mountain building. It is here suggested that the folding of mountain ranges may be produced by the frictional drag of moving portions of the asthenosphere, and that these movements may be convective and result from its unequal heating by radio-active elements.

The earth is gaining heat energy from the breaking up of radio-active molecules and the liberation of some of the energy of these heavy elements in the form of heat. It is at the same time losing heat by conduction through the crust and subsequent radiation. Now, it has not been possible to equate these two quantities, the average quantity of radium found in rocks by Strutt being many times greater than that necessary to make good the loss by radiation into space. This disagreement, which is doubtless due to causes not yet ascertained, does not in any way invalidate the established facts that the earth is both gaining and losing heat.

The author is aware that many geologists have attempted to explain mountain building in terms of a cooling and contracting earth, but were such the case the contraction must have been continuous and progressive with no periods of complete rest, with the result that the whole crust would be in compression, whereas the most characteristic phenomena of the throwing up of mountain chains are that they are *local in place and occasional in time*. More recently this hypothesis has been modified by supposing that the contraction only takes place at long intervals, and is due possibly to molecular rearrangement in the interior.

In addition to this "curiously local distribution of . . . compression", as Oldham has called it, it must be remembered that the most intense compression and folding occurs in the centre of a mountain range, and that the folding becomes less on the outskirts. It has several times happened that the upheaval has affected freshly deposited material and has followed a long period of sinking, e.g. Malvernian, Armorican, and Alpine foldings. In contrast to the folded districts large portions of the crust have been but little

disturbed for long ages, normal faulting possibly indicating a state of slight tension. The phenomena of fissure eruptions indicates that parts of the crust have been in considerable tension, which is further borne out by the wide evidence Professor J. W. Gregory has gathered that fiords are tension clefts and rift valleys. It would be out of place to enlarge on this aspect of the matter, but I desire to indicate that geological evidence does not readily support the hypothesis of a contracting earth.

The theory of isostatic adjustment may be regarded as well authenticated from the work of Barrell in the United States and Oldham in India. The tendency to this adjustment must follow as a consequence of the simple principles of hydrostatics once it is conceded that there underlies the crust material that will flow under long-continued, but not necessarily great, stresses; on the other hand, the completeness of such an adjustment must be conditioned by the strength of the crust to resist distortion.

It is evident from the many types of igneous rock that are met with on the surface that the interior of the earth cannot be homogeneous in composition, hence it may be assumed that radio-active elements are not evenly distributed, and that where they exist in greater quantity there will result local heating. Now, where this occurs between the crust and the Hayford compensation level, the result could be that portions of the crust might be elevated considerably in relation to the crust above the lesser heated regions. There is evidence that the change of density in the lower parts of the crust might be greater than that produced by mere thermal expansion, for instance, the density of one mode of a particular rock has been shown by Dr. L. L. Fermor to differ from that of its norm by as much as twenty per cent, so that the slow melting of such a rock might easily produce a considerable change of density. Such density differences might continue to increase during long periods of time during which material would be removed by denudation from the elevated tracts and deposited in the relatively depressed tracts, causing these to sink still lower, as has been the case in the Gangetic trough. These conditions might be terminated by a convective movement, which would in a comparatively short time establish more stable conditions under the crust. A movement of this kind occurring in one place might well start movements in adjoining districts where unstable conditions had been attained, and so the convective movements might spread until they became world-wide. The effect of such movements would be to act as a drag on the under surface of the crust, drawing out the lower portions into schists and gneisses and disrupting the upper portion as it was moved. This would be most marked in the lower layers of the crust. These would be dragged into folds and puckered, while the higher layers would not be so much affected. The gaps thus formed in the lower strata would be filled by molten material from below, which might reach the surface in places.

Should a relatively cooler portion of the asthenosphere be situated between two hotter portions, all being at about the same level, then, when movement commenced, there would be two opposing currents dragging the under surface of the crust, which would be crumpled along a line perpendicular to the currents. There would thus arise a line of folding above the region where the asthenosphere was sinking, and the crust outside the moving regions would be in tension. Now the folded mass, being lighter than the asthenosphere, would float in it and project above the general level of the crust. It would thus be a mountain chain with light roots, and denudation of the protruding mass would cause a further rise, for as many of the cracks and folds would be approximately vertical, isostatic adjustment would be relatively easy, because the broken crust would have little strength, and this might continue until denudation had removed the mountain chain and only traces remained, as in Devonshire.

Away from the centre of folding, the underdrag of the slowly moving material would make its effects felt in various ways. Where there existed old lines of folding there would be a tendency to accentuate these, and to increase any want of symmetry, the steeper limbs of the anticlines indicating the direction of approach. For instance, the Weald, Purbeck, and Ridgeway anticlines have their steepest dips on the north or north-west, being in agreement with the idea of an undercurrent from north to south, i.e. towards the Alpine axis of folding. The effect of the underdrag on rocks that were brittle and without a thick cover might well produce movements along numerous slide planes, such as have occurred in Scandinavia.

In this connexion I desire to draw attention to a remark made by Mr. Bernard Smith before the Geological Society on the 23rd June, 1920, to the effect that he and Mr. C. B. Wedd had come to the conclusion that certain structures in North Wales had been produced by the deeper seated rocks moving first and dragging those above.

This hypothesis furnishes a possible explanation of the following:—

(*a*) The intense folding of mountains along well-defined lines while rocks sometimes at no great distance show no indication of compression, and also the fact that the lower beds are usually more distorted than the upper.

(*b*) The folding often follows a long period of deposition.

(*c*) Old axes of folding or "lines of weakness" are often accentuated.

(*d*) The formation of fiords and fissure eruptions.

(*e*) The change of type of magma erupted in a particular district after long geological intervals, as on the Peruvian coast and in the Great Rift Valley.

(*f*) The formation of gneisses and schists from plutonic and other rocks.

The hypothesis suggests a source or energy ample for the

mechanical work to be done, but its chief weakness is that it is not supported by sufficient evidence of tension in the crust flanking the lines of folding. For instance, there is evidence that the fissure eruptions of the North of Ireland and Scotland are of earlier date than the Alpine folding, and that the two did not take place concurrently, as is here suggested.

Whatever may be the main cause of earth movements, there are no doubt many minor causes which affect the results. It is possible, for instance, that the tidal waves in the crust which Michelson has shown by the use of his interferometer to attain a height of 2 or 3 feet, may determine the formation of north and south joints, especially in the tropics, and affect the edges of oceanic areas.

Fauna of the Brachiopod Beds at Cauldon, Staffs.

By W. E. Alkins, M.Sc.

In a recent note[1] Mr. J. Wilfrid Jackson, F.G.S., and the writer mentioned the occurrence at Cauldon, Staffordshire, of highly fossiliferous limestones, resembling those of the "Brachiopod-beds" of Castleton, Park Hill, Narrowdale, Thorpe Cloud, and other stations on the north-west, west, and south-west of the Staffordshire-Derbyshire limestone massif. It will perhaps be of interest to put on record the fauna of these beds, as far as it has yet been worked out, since the conditions under which they occur renders it highly improbable that any considerable amount of material will ever be available from them, and since they represent a phase which does not, so far as is known at present, occur to any extent in the more immediate neighbourhood of this station.

At the village of Cauldon, very pure and very fossiliferous soft white limestones have been found to occur at the east end of the churchyard, whence they extend some little distance south in the direction of the large quarry on Cauldon Low, as is shown by a small exposure in a field between the church and the Waterhouses Road. Unfortunately there are no large exposures of these beds, and the material on which this note is based has been obtained almost entirely from stone quarried out during the sinking of grave-shafts. At the west end of the churchyard the limestone is totally different in character; it is hard and slaty, and contains practically no fossils. The absence of sections renders obscure the relationship of these beds to each other, and also to the massive limestones of Cauldon Low itself, which appear to belong to a relatively low horizon—C–S_1. A noteworthy feature is the occurrence of many "pot-holes" in and about the churchyard.

According to the 1 inch Geological Survey map (72 N.E.), the limestone here is cut off from the Pendleside Series by faults on the north-west and north-east sides, but no faults are shown between Cauldon Low and Cauldon Church. The slight eminence on which the

[1] Geol. Mag., Vol. LVI, 1919, p. 59.

church stands is formed by a block of limestone projecting from the main mass, and its structure is an interesting problem.

The fauna which has been obtained from these beds is given in the tables below. An attempt has been made to refer each species to a published figure, in the hope that this will increase the value of the lists. As is always the case, in studying a large suite of specimens from the brachiopod beds many forms cannot be matched against illustrations; to these no reference is made.

BRACHIOPODA.

(References to plates and figures without further remark are to Davidson's Monograph.[1])

Dielasma hastatum (Sow.). Pl. i, fig. 12.
Terebratula sacculus (Mart.). Pl. i, fig. 27.
T. vesicularis de Kon. Pl. ii, fig. 5.
Athyris expansa Phil. Pl. xvi, fig. 16.
A. lamellosa l'Eveille. Pl. xvi, fig. 1.
A. planosulcata Phil. Pl. xvi, figs. 2, 4, 5.
A. subtilita Hall. Pl. xvii, fig. 10.
Seminula globularis (Phil.). Pl. xvii, fig. 15.
Retzia radialis (Phil.). Pl. xvii, figs. 19, 20.
Spirifer bisulcatus Sow., var. *semicircularis* Phil. Pl. vi, figs. 1, 2.
Sp. bicarinatus M'Coy. Pl. viii, fig. 18, exactly.
Sp. clatharatus M'Coy. Pl. iii, fig. 6.
Sp. duplicicosta Phil. Pl. iv, fig. 5.
Sp. grandicostatus M'Coy. Pl. v, figs. 38, 39; pl. vii, figs. 8-11.
Sp. integricosta Phil. Pl. ix, fig. 16.
Sp. cf. *paucicostatus* M'Coy. Pl. iv, fig. 12.
Sp. cf. *pinguis* Sow. Pl. x, fig. 7, but finer ribbing.
Sp. striatus (Mart.). Pl. ii, figs. 15, 16, exactly.
Sp. triangularis (Mart.). Pl. v, figs. 18–21.
Sp. triradialis Phil. Pl. ix, fig. 10.
Brachythyris rhomboidalis M'Coy. Pl. xii, fig. 6.
Martinia glabra (Mart.). Pl. ix, figs. 3, 7; pl. xii, fig. 2.
Reticularia elliptica (Phil.). Pl. xiii, fig. 3
R. lata (Brown). Pl. xii, fig. 1.
R. lineata (Mart.). Pl. xiii, figs. 4, 5, 6.
Rhynchonella trilatera de Kon. Pl. xxiv, figs. 24, 25.
Rhynchonella, sp. Pl. xix, figs. 9, 10 (dwarf).
Pugnax pleurodon (Phil.). Pl. xxiii, fig. 2.
P. pugnus (Mart.). Pl. xxii, fig. 4, but smaller.
Camarophoria crumena (Mart.). Pl. xxv, figs. 4, 5.
C. globulina, var. *rhomboida* (Phil.). Pl. xxiv, fig. 10.
C. rhomboida (Phil.). Pl. xxiv, figs. 11, 12.
C. seminula (Phil.). Pl. xxiv, figs. 13–16.
Camarophoria, sp. Pl. xxv, fig. 9, exactly.
Orthis keyserlingiana de Kon. Pl. xxviii, fig. 14.
Rhipidomella michelini (l'Eveille). Pl. xxx, figs. 8, 9.
Schizophoria resupinata (Mart.). Pl. xxix, fig. 2; pl. xxx, fig. 1.
Leptæna analoga Phil. Pl. xxviii.
Orthotetes crenistria (Phil.). Pl. xxvii, fig. 8.
Productus aculeatus (Mart.). Pl. xxxiii, figs. 16, 17.
Pr. concinnus Sow. Pl. xliii, figs. 9, 10.
Pr. cora d'Orb. Pl. xxxvi, fig. 4.
Pr. costatus Sow. Pl. xxxii, fig. 3, exactly.
Pr. elegans M'Coy. Pl. xliv, fig. 15.

[1] T. Davidson, "British Carboniferous Brachiopoda": *Palæont. Soc., London*, 1857–62.

Pr. fimbriatus Sow. Pl. xxxiii, figs. 13, 14.
Pr. cf. *fimbriatus* (Sow.), Vaughan, *Quart. Journ. Geol. Soc.*, vol. lxii, 1906, pl. xxx, fig. 6
Pr. longispinus Sow. Pl. xxxv, fig. 8.
Pr. margaritaceus Phil. Pl. xliv, figs. 5, 8.
Pr. martini Sow. Pl. xliii, fig. 7; pl. lv, fig. 11.
Pr. mesolobus Phil. Pl. xxxi, figs. 7, 8.
Pr. plicatilis Sow. Pl. xxxi, fig. 3.
Pr. punctatus Mart. Pl. xliv, figs. 14, 18.
Pr. pustulosus Phil. Pl. xli, fig. 1.
Pr. scabriculus Mart. Pl. xlii, fig. 6.
Pr. semireticulatus Mart. Pl. xliii, fig. 1.
Pr. spinulosus Sow. Pl. xxxiv, figs. 18, 19.
Pr. youngianus Dav. Pl. xxxiii, figs. 21, 22.
Chonetes hardrensis Phil. Pl. xlvii, fig. 12.
Ch. papilionacea Phil. Pl. xlvi, figs. 3, 4; one specimen has the hinge-line four inches long.

LAMELLIBRANCHIATA.
(References to Hind's Monograph.[1])

Posidoniella vetusta Sow. Vol. i, pl. v, figs. 9–11.
Parallelodon bistriatus Portl. Pl. ix, figs. 5–12.
Edmondia accipiens Sow. Pl. xxxvii, figs. 8–16.
Leiopteria laminosa Phil. Vol. ii, pl. iii, figs. 4–9.
Eumicrotis hemisphæricus Phil. Pl. vii, figs. 1–6.
Pterinopecten tesselatus Phil. Pl. ix, figs. 8–11.
Pt. eximius de Kon. Pl. xi, figs. 13, 14.
Pt. dumontianus de Kon. Pl. xiv, figs. 1, 2.
Aviculopecten murchisoni M'Coy. Pl. xiv, figs. 3-7.
A. interstitialis Phil. Pl. xiv, figs. 16–21.
A. clathratus M'Coy. Pl. xv, figs. 1–6.
Pseudamusium concentrico-lineatum Hind. Pl. xx, figs. 7–10.
Ps. anisotum Phil. Pl. xxi, figs. 13–20.
Schizodus oboratus M'Coy. Pl. xxiv, fig. 14.

TRILOBITA.
(References to Woodward's Monograph.[2])

Phillipsia derbiensis Mart. Pl. i.
P. gemmulifera Phil. Pl. iii, fig. 5.
P. scabra H. Woodw. Pl. ix, fig. 5*a*.
Brachymetopus ouralicus de Vern. Pl. viii, figs. 1–8.
Griffithides carringtonianus Eth. MS. Pl. ix, fig. 6*a*.

GASTROPODA.

Patella rycholtiana de Kon. *Descr. An. Foss.*, 1842–44; pl. xxiii, fig. 5.
Capulus trilobus Phil. *Geol. Yorks.*, pl. xiv, figs, 12, 13.
Bellerophon costatus Sow. De Kon. (loc. supra cit.), pt. iv, pl. x, figs. 1–3.
B. tenuifascia Sow. De Kon. pt. iv, pl. xxxviii, figs. 8–10.
Phanerotinus nudus Sow. De Kon., pt. iv, pl. xxii, figs. 16–18.
Straparollus dionysii de Mont. De Kon., pt. iii, pl. xiv, figs. 16–18.
Str. pileopsideus Phil. De Kon., pt. iii, pl. xiv, figs. 22–24.

In addition there are several corals, of which *Cladochonus bacillaris* alone has been identified; *Chaetetes tumidus*, *Fenestellidæ*, and a number of unidentified Brachiopoda and Gastropoda.

The writer's thanks are due to Mr. J. Wilfrid Jackson for much very valuable assistance in the identification of species.

[1] W. Hind, "British Carboniferous Lamellibranchiata": *Palæont. Soc., London*, 1896–1905.
[2] H. Woodward, "British Carboniferous Trilobites": *Palæont. Soc., London*, 1883–4.

An Outline of Chinese Geology.

By J. S. Lee, M.Sc., Birmingham.

(*Continued from p. 329.*)

To the south of the Tsing-ling Range the above classification of the Sinian System no longer holds good. The Kisinling Limestone of western Hu-peh [1]—a massive grey limestone grading downwards into a slaty limestone and slates—has yielded in its upper part gigantic *Orthoceras*, or the pagoda stone, and other Ordovician fossils; and is therefore regarded as equivalent to the upper and the middle part of the Sinian in north-east China. Unconformably underlying the Kisinling Limestone, a glacial deposit, the Nantou Tillite, was found by Willis and Blackwelder at Nan-tou, near the north-western entrance of the I-chang Gorge (about long. 111° 10′ E., lat. 30° 45′ N.). Mr. V. K. Ting has verbally informed the writer that this interesting deposit extends towards the south-west for a considerable distance. The occurrence of *Asaphus* and *Trinucleus* to the south of Ning-kiang (about long. 106° E., lat. 32° 45′ N.) makes it highly probable that, there, the upper Sinian is exposed among other folded Palæozoic strata.[2]

Further south, in eastern Yun-nan, the Cambro-Ordovician rocks [3] present an entirely different facies to that of north-east China. Nevertheless, they contain the same fauna, at least throughout the Cambrian formation. According to Dr. Deprat, the Ordovician there consists of sandstones, shales, and marls, and the Cambrian consists of an upper group of argillaceo-arenaceous rocks and a lower group of compact grits with intercalated limestone. A local stratigraphical break appears to exist between the Ordovician and Cambrian.

Loczy regards the limestone that occurs to the east of Pa-tang (about long. 99° E., lat. 30° N.), and its associated metamorphic strata, as a Sinian formation. Richthofen considered at one time or another three successive series of rocks as Sinian representatives in south-east China. They are:—

c. Matsu Limestone. A dark-grey siliceous limestone containing sandy and clayey slates, hornstones, and calcite-veins. Typical exposure is found in the Matsu-shan, on the northern side of the Poyang-hu.

b. Lushan Slate. Grey-green, fine-grained slates with characteristic quartz-veins which are often auriferous; typically occur in the Lu-shan, north of the Poyang-hu.

The Kauling Slate that occupies large areas in the provinces of Kiang-si and southern An-hwei is possibly identical with this series.

a. Tahau Sandstone. Massive, quartzitic red sandstone forming the bulk of the Tahau-shan, south-east of Ta-tung, southern An-hwei.

It should be emphatically pointed out that both Loczy and Richthofen are unable to produce palæontological evidence for their

[1] Willis, op. cit., vol. i, pt. i, pp. 269–72.
[2] *China*, vol. ii, pp. 597–601.
[3] Deprat, op. cit., 1re Partie, pp. 55–63.

determination of age. The black-brown crystalline limestone of Lun-shan[1] (about long. 119° 30′ E., lat. 32° 5′ N.), in the lower Yang-tze Valley, may, however, be assigned to the Sinian without any hesitation, for it contains abundant characteristic oolites and globulites, and several Ordovician species; further, it is overlain by a graptolite-bearing shale.

Having briefly referred to the distribution and successions of the Sinian rocks, we now proceed to interpret their significance. During the transitional period from the Wutai-Nankou Era to the early Cambrian time or the Manto epoch, the whole of northern China having been already eroded to a vast peneplain, gradually and uniformly came under the transgressive Sinian water. On the other hand, the south and the south-east of the country were then probably dominated by mountains or highlands from which presumably was derived the gritty material that forms the lower Cambrian beds in eastern Yun-nan. In central China little is known about the geographical distribution and the stratigraphical position of the Nantou Tillite. We are, as yet, unable to offer any solution to many interesting scientific problems: whether, for instance, such an early glaciation was due to the general lowering of temperature in northern and central China by some secular cause or due to the great elevation of land surface resulting from the post-Wutai-Nankou and pre-Cambrian movement; and whether the glaciation did really take place in the early Cambrian time as maintained by Willis and Blackwelder. For further research the similar cases in Norway and North America should be naturally brought to our comparative study.

The drowned ancient land continued to subside under the Sinian sea, leading to the deposition of finer and calcareous material. Palæontological evidence also points to the same effect. The Manto sea with its *Redlichia* fauna undoubtedly extended from Shan-tung, Yun-nan to the Punjab and Australia. There was little faunal communication with the western world. But soon after the commencement of the Middle Cambrian period the *Dorypyge* or the *Ptychoparia* fauna began to thrive. The Sinian sea by this stage was thrown open to free migration of organisms, and consequently swarmed with cosmopolitan forms of life. Walcott has demonstrated that the *Dorypyge* fauna of China is not only present in western North America, but associates with the *Paradoxides* fauna of north-west Europe.

Although the Sinian sea effected a sweeping transgression, the main ranges of the Tsing-ling and the Nan-shan region, however, stood above the water for the most part, if not the whole of the period. No rocks of demonstrable Sinian age have yet been found in these

[1] *China*, vol. iii, p. 718. The age of the Lunshan Limestone is undoubtedly discussed by Mr. V. K. Ting in a paper on "The Geology below Wu-hu", *Hwangpu Conservancy*, July or August, 1919, Shanghai. Unfortunately, the writer is unable to obtain the paper.

mountains. The intense folding that prevails in all parts of these ranges is certainly an excellent condition for the preservation of extensive strata if they were once present; and the peculiar lithology so widely prevalent with Sinian rocks, together with their highly fossiliferous nature, would form conspicuous landmarks that could not have escaped the notice of so many keen observers if the rocks were there.

From early Cambrian time to the end of the Ordovician period, or probably later, there was little alteration of the distribution of land and sea in China. The processes of denudation and deposition were allowed to continue their operation in a monotonous and undisturbed manner. Eastern Yun-nan is the only area that was in a relatively unstable condition. The intercalation of limestones in the lower gritty series, the grits in the upper argillaceous strata of the Cambrian formation, and the local unconformity between the Ordovician and Upper Cambrian are probably all due to the oscillation of the sea-floor. Igneous activity is practically unknown in China throughout the whole of the Sinian period.

The Silurian and Devonian.

The results of geological researches and mining records hitherto obtained in northern China have conclusively shown that in this vast area the Sinian System is separated from the overlying Shansian coal-bearing rocks by an unconformity of great magnitude. Although the contact between the two is generally of concordant nature, the hiatus of life sequence proves the existence of an unconformity beyond any doubt. The top of the Sinian contains Ordovician fossils as already mentioned; near the base of the overlying Shansian System marine fossils have been found. Though the exact age indicated by these fossils is still a matter of dispute, they undoubtedly represent the life of a period not earlier than the Lower Carboniferous.

From these palæontological data it follows that Silurian and Devonian deposits are practically absent in northern China, namely, in the provinces of Manchuria, Shan-tung, Chi-li, Shan-si, Ho-nan, and probably Shen-si. Either during the whole of these periods or a part or parts of them these provinces must have been subjected to uniform erosion, consequent to a broad epeirogenic movement.

Lorenz speaks of Upper Devonian transgression [1] in Shan-tung on account of the presence of a series of coarse strata having a maximum thickness of not more than 300 feet. These rocks lie between the eroded Sinian limestone and a fossiliferous zone which is doubtfully assigned by Professor Frech to the Lower Carboniferous. In the absence of further evidence it would appear risky to accept Lorenz's hypothesis.

[1] Lorenz, "Beitrage z. Geol. u. Pal. von Ostasien, etc.": *Zeits. d. d. Geol. Gesell.*, vol. lvii, pp. 448–50.

From the Nan-shan Ranges Obrutchov reports the occurrence of fossiliferous Devonian generally consisting of a series of red and green sandstones and slates being occasionally underlain by a limestone which is also assigned to the Devonian; and Silurian (?) consisting of highly metamorphosed strata such as quartzite, crystalline limestone, and even schist.[1]

In the western Tsing-ling to the north of Liu-pa (about long. 107° E., lat. 33° 40′ N.) Richthofen found a mighty sequence of limestone and sandstone apparently folded in an anticline. He maps them as "Silurian and Devonian".[2]

Silurian and Devonian fossils[3] have been found at many localities in the mountains bordering the northern and western sides of the Great Red Basin of Su-chuan. It appears that a continuous belt of marine Siluro-Devonian formation runs along the north-west side of the Red Basin. The Devonian; on the western side of the basin, seems to rest unconformably upon the older rocks; but merges as a rule into the Lower Carboniferous without any break.

To the east of the Great Red Basin or in the western part of Hu-peh, Willis and Blackwelder distinguish a Sintan Formation[4] chiefly composed of a green shale being conformably underlain by the Kisinling Limestone of Sinian age, and conformably overlain by the Wushan Limestone of Carboniferous age. The occurrence of this series of shale in the Yang-tze gorges is also reported by Richthofen,[5] Abendanon,[6] and others.[7] Abendanon holds that the Sintan Formation underlies the Kisinling Limestone. This, however, does not appear to be the case. It is quite possible that the argillaceous series in the lower part of the Kisinling Limestone may have locally developed to a shaly facies resembling the Sintan series. Hence there arose the dispute. By a feasible argument which we need not discuss here, Willis and Blackwelder assign the Sintan Formation to the Siluro-Devonian period. What deserves our attention in this connexion is the occurrence of a thick series of green shale among the Siluro-Devonian strata exposed near the Ning-kiang district further west. According to Richthofen's description this shale is lithologically similar to the Sintan rocks.

In the lower Yang-tze Valley, apart from the limestones and the graptolite-bearing shale of the Lun-shan, west-south-west of Chin-kiang, we do not hear of the occurrence of demonstrable Silurian rocks. Of the Devonian, Kingsmill and Richthofen describe

[1] C. Diener, "Die wichtigsten geogr. u. geol. Ergeb. d. Reisen Obrutschews in zentralen u. westlichen Nanschan": *Peter. Mitt.*, vol. xlviii 1902, pp. 97–106.

[2] *China*, vol. ii, pp. 582–4, Tafel vii; Atlas Erste Abt. Tafel 24.

[3] Loczy, op. cit., vol. i, pp. 432–5, 682–3; vol. iii, p. 22 et seq. *China*, vol. ii, pp. 595–601; vol. iv, pp. 37–102. *Journ. Geol. Soc. Tokyo*, 1915, No. 261, pp. 64, 67; No. 263, p. 87.

[4] Willis, op cit., vol. i, pt. i, pp. 273–4.

[5] *China*, vol. iii, pp. 106–8.

[6] Abendanon, "Die geol. d. Roten Beckens": *Zeits. d. d. geol. Gesell.*, vol. lix, pp. 197–203; *Journ. Geol. Chicago*, vol. xvi, pp. 588–616.

[7] Noda, *Bull. Imp. Jap. Geol. Surv.*, vol. xxv, No. 1, 1915, p. 67.

two series or two facies of deposits:[1] the one is a semicrystalline, siliceous dolomite such as those exposed in the vicinity of Kiu-kiang (about long. 116° E., lat. 29° 45′ N.), in the Tung-ting-shan of the Tai-hu, southern Kiang-su, and in the hills between Nan-king and Chin-kiang. The other is a group of quartzitic sandstones and conglomerates such as those exposed in the Lu-shan, north-west of the Poyang-hu, Kiang-si; in the Hsiau-hau-shan, Tung-kwan-shan, and Tung-lu-hsien, southern An-hwei. The relation between these two series or facies is altogether obscure at present. Richthofen's report from the Hwa-shan, between Nan-king and Chin-kiang, and Kingsmill's report from near the Tai-hu, however, seem to agree in showing that the dolomitic limestone overlies the sandstone group. On the other hand, in the Hsi-hsia-shan, east of Nan-king, the sandstone group is directly overlain by a marine formation of Lower Carboniferous age. The lack of direct palæontological evidence inevitably invites much doubt as to the true age of these rocks.

In contrast to northern China, namely, the part north of the Tsing-ling Range, the Devonian formation is well developed in the south-western provinces, that is in Hun-nan, Kwang-si, Kwei-chou,[2] and Yun-nan. It generally consists of a highly fossiliferous marine limestone with or without the intercalation of shaly strata, and contains a fauna intimately related to the marine Devonian fauna of Europe. To demonstrate this close faunal affinity, nothing would be more emphatic than pointing out the occurrence in the Chinese Devonian of such familiar characteristic forms as *Spirifer curvatus*, *S. verneuili*, *S. undiferus*, *Atrypa reticularis*, *A. aspera*, *Rhynchonella* (*Pugnax*) *pugnus*, *Productella subaculeata*, *Uncites gryphus*, *Chonetes orientalis*, *Cyathophyllum cæspitosum*, *C. roemeri*, *Favosites sphæricus*, *Calceola sandalina*, *Alveolites*, *Aulopora*, etc.

Among the south-western provinces Devonian as well as Silurian is best known in Yun-nan. Loczy years ago observed in western Yun-nan a Silurian limestone containing characteristic large Cystidian plates.[3] Recently Dr. Deprat found in eastern Yun-nan, a series of argillaceous sandstones yielding Silurian fossils, and argillaceous limestones with abundant Devonian fossils. Though the Devonian formation is somewhat variable in its lithological

[1] *China*, vol. ii, pp. 559, 562, 722, 730, 741. Kingsmill, "Note on some outlying Coal-field, etc.": *Brit. Roy. Asiat. Soc. N. China Br.*, ser. II, No. 111, pp. 102–3.

[2] Frech, "Ein neues Vorkommen des Stringocephaln-Kalk in Hu-nan": *Centralbl. f. M.G.*, N.C. 7, 1914. Davidson, *Quart. Journ. Geol. Soc.*, vol. xxii, 1853, pp. 353–9. Leclère, op. cit., p. 26. Douville, *C.R. Acad. Sci. Paris*, vol. cxxx, pp. 592–5; *idem*, vol. cxl, pp. 692–4.

[3] Loczy, op. cit., vol. i, p. 767; *idem*, vol. iii, p. 21. F. A. Bather discusses the structure of the Cystidea from Yun-nan in some details (GEOL. MAG., Dec. VI, Vol. V, No. 11, 1918); F. R. Cowper Reed describes several species of Cystidea in the Ordovician and Silurian faunas from western Yun-nan, which include, according to Miss Elles, a number of species of Llandovery Graptolites (*Palaeont. Indica*, N.S., vol. vi, No. 3, 1917).

character, the faunistic zones, which are no less than eighteen in number as established by Deprat,[1] persist throughout a wide area.

The Devonian formation is separated at many localities in the region of eastern Yun-nan, Kwang-si, and Kwei-chou from the older rocks by an unconformity. The occurrence of *Spirifer tonkinensis* in the Nan-ti district, south of the provincial capital of Yun-nan, has, however, led Deprat to assert the presence of transitional beds from the Silurian to the Devonian. The Upper Devonian passes into the Lower Carboniferous in perfect conformity throughout the south-western provinces.

Now let us examine the facts so far described from a historical point of view. In the latter part of the Sinian time, namely, the Bala or Llandovery epoch, the whole of northern China was still under the cover of a vast ocean. The Nan-shan and the Tsing-ling Ranges that stood out from the early Sinian water were by this time at least partially submerged. The early Silurian sea evidently extended from northern China to the south-west covering the present Yang-tze Valley, either the whole or the western part of Su-chuan, the greater part of Yun-nan, and farther spread itself out towards the direction of Indo-China, Burma, and beyond. This sea was undoubtedly but a part of the great Silurian ocean that extended over the present Eurasian Continent and North America, for Richthofen, in journeying from Ning-kiang to Tshau-tien, found in highly fossiliferous limestones a colony of widely distributed Silurian corals, together with a number of cosmopolitan Brachiopods, such as *Favosites, Halysites, Heliolites, Amplexus, Orthis calligramma, Spirifer radiatus, Leptæna sericea, Strophomena corrugatella*. The continent during the Silurian time lay in the south-east of the country.

On the close of the Silurian period a general earth-movement took place in Asia involving at least the south-western provinces of China Proper. The nature of the movement was not intensive and temporary, but extensive and lasting. As southern China was undergoing progressive subsidence, the Lower and the Middle Devonian sea gradually advanced towards the north-east. The pre-Devonian land in the provinces of Kwei-chou, Kwang-si, and probably Hu-nan was consequently submerged.

What, then, had happened to northern China while the subsidence was going on in the south? Richthofen is of the opinion that during the Devonian time northern China was under an abysmal ocean in which very little material was deposited.[2] We need not raise all the difficulties that such a hypothesis has to encounter. Tectonic consideration alone seems sufficient for the solution of this problem. In view of the fact that an anticline or an anticlinorium is generally accompanied by a syncline or a synclinorium, and vice versa, might we not expect a broad, slow upheaval of land in a region adjoining one where subsidence was continually taking place? Might not the

[1] Deprat, op. cit., 1re Partie, p. 69 et seq.
[2] *China*, vol. ii, p. 713.

general absence of Silurian and Devonian strata in the vast area of northern China be fitly interpreted as the result of a broad epeirogenic movement accompanying the slow Devonian transgression in the southern part of the country? The region on the south of the Tsing-ling belt apparently behaved as the fulcrum.

During the later part of the Devonian period China experienced little geographical and geological changes. Uniform subaerial denudation in the north progressed side by side with tranquil sedimentation in the south. In the meantime, the climatic conditions became suitable for exuberant growth of vegetation on the land; cosmopolitan types of organisms swarmed in the open ocean. With such a multitudinous development of plant and animal life the great coal-forming period was inaugurated in eastern Asia.

The Anthracolithic or Carboniferous-Permian.

The upper Palæozoic rocks are well developed in all parts of China, including the high mountain ranges of the Tsing-ling and the Nan-shan. The continuous and conformable nature of the formation that represents the transitional period from the Carboniferous to the Permian renders it difficult to select a definite plane for dividing the Carboniferous from the Permian as in the case of north-western Europe. The term "Anthracolithic", first introduced by Dr. W. Waagen, and recently adopted by Professor E. Haug for denoting the whole of the Carboniferous and Permian period, seems to be particularly suitable for Chinese geology.

Two facies of the Anthracolithic Formation are recognizable in China: the continental facies with thick seams of coal is principally distributed in the northern provinces, namely, Manchuria, Shan-tung, Chi-li, Shan-si, Ho-nan, Shen-si, and probably including the eastern part of Kan-su. This coal-bearing series is also known as the Shansian System. The marine facies with massive limestones is found in the southern provinces, namely, to the south of the Tsing-ling Range. In the lower Yang-tze Valley, the Tsing-ling Range, and the Nan-shan Ranges these two facies are more or less equally represented. The facies-character of the formation is, however, not absolutely confined to the several regions in such a way as outlined above. In the marine facies coal seams and other terriginous deposits are not absent; while in the continental facies we find seams of true marine limestones which decrease in number and thickness towards the north. They entirely disappear in the Wan-ping coal-field, west of Peking, reappearing in the Kai-ping coal-field, eastern Chi-li, and Manchuria. Thanks to these intercalations, ere long we shall be able to attempt an accurate correlation of the Shansian strata.

Throughout northern China the Shansian formation generally rests at once on the Sinian limestone; the latter is sometimes erroneously called by miners the "Carboniferous Limestone" or the "Mountain Limestone". Richthofen, too, regarded the Sinian limestone in several parts of Shan-tung as the "Kohlenkalk". The upper

part of the Shansian System marges into a yellowish or reddish sandstone of considerable thickness, moderately coarse in texture and barren of fossils. This sandstone is often termed the "Plateau Sandstone" or the "Supracoal Sandstone".

The Shansian System is divisible in the province of Shan-si into two series in the following descending order:—

b. Productive Measures. Variegated sandstones with subordinate sandy shale containing anthracite seams of a thickness varying from 12 to 30 feet.

a. Taiyang Series.[1] Alternating beds of limestones, ironstone-bearing shales, sandstones, and fire-clays with occasional seams of coal; capped in places by a highly fossiliferous black Fusulinidea limestone which often contains flints.

In the other provinces of northern China the general lithological character of the Shansian Formation is much the same. The Fusulinidea of the flinty limestone, as well as the ironstone-bearing beds, persist throughout a remarkably wide area. According to the *Record of the Work of the Geological Institute* this ferruginous stratum decreases in thickness from southern Shan-si towards the north, ranging from 37 mm. to a few metres. In western Shan-tung the Shansian System is locally known as the Poshan Series.[2] Apart from the intercalation, in the upper part of this series, of contemporaneous lava and tuff, there appears no notable lithological difference from its equivalent in Shan-si.

Several assemblages of marine fossils were found by Richthofen in the provinces of Shan-tung and Shan-si from the marine intercalations of the Shansian System. According to Professor Frech,[3] the fauna which consists of *Productus semireticulatus*, *P. scabriculus*, *P. longispinus*, *P. giganteus*, *Spirifer duplicicosta*, *S. bisulcatus*, *S.* (*Martinia*) *glabra*, *Loxonema walciodolense*, *Macrocheilus* cf. *intermedius*, *Naticopsis* cf. *globulina*, etc., is as a whole comparable with that of the Viséan Limestone of Europe. That is to say, at least the lower part of the Shansian System belongs to the Lower Carboniferous. After an examination of several species of Brachiopods obtained from the limestone member of the Shansian System, Douville failed to arrive at any definite conclusion with respect to the age of their containing rock. He doubts whether the limestone is comparable with the black marble of Tonkin; the latter is generally considered as belonging to the Westphalian or possibly some earlier stage. Girty,[4] after studying the marine fossils, including the species *Squamularia* cf. *perplexa*, *Chonetes* aff. *flemingi*, from Shan-tung and Shan-si, compares the Shansian System with the Pennsylvanian, viz. the Upper Carboniferous of North America; while Hayasaka[5] endeavours to show that the marine fossiliferous zone of the Poshan Series is of the youngest Carboniferous age.

[1] *China*, vol. ii, pp. 406, 411. [2] Ibid., p. 203.
[3] Ibid., vol. v, pp. 63–76.
[4] "Upper Palæozoic Fossils": *Proc. U.S. Nat. Hist. Mus.*, 1908, pp. 37–48.
[5] *Journ. Geol. Soc. Tokyo*, vol. xxiv, No. 283, 1917, pp. 169–97.

(*To be continued.*)

REVIEWS.

DER BAU DER ERDE. By L. KOBER. pp. 321, with 2 plates, and 46 text-figures. Berlin: Gebrüder Borntraeger. 1921. Price 80 marks.

ALTHOUGH speculations on the plan of the earth, the distribution of land and sea, of mountain ranges, and other geographical features, are a subject of never-failing interest, most students of geology have come to the conclusion that life is not long enough to read Suess. *The Face of the Earth* is heavy going in any one of the three versions, the conclusions are not always clear, parts are out of date, and, owing to the long period that elapsed between the appearance of the first and last volumes the author's views had necessarily undergone important changes. In recent years many new facts have come to light and prevalent ideas have had to undergo revision. The book under review gives in small compass a summary of the present state of our knowledge on the structural features of the earth. It cannot be described as altogether an impartial statement, since the author is obviously arguing in favour of his own hypothesis. What that hypothesis is will be discussed later. The book is written in a clear and simple style, in short sentences very unlike the usual German manner, in fact, in places almost telegraphic, and occasionally the meaning of a sentence is rendered somewhat obscure by the absence of a principal verb.

The book begins with a discussion of the nature of the earth's crust, its thickness and composition, and its morphological subdivisions, emphasizing the contrast between the massive and permanent continental blocks and the folded regions, the latter originating as geosynclinals. For these last elements the word "Orogen" is employed, a word difficult to translate neatly, but perhaps best expressed as *orogenic zone*. Much importance is rightly attached to the different facies of sedimentation and the close connexion between types of earth movement and the Atlantic and Pacific igneous rock-families of Harker is strongly insisted on. The writer commits himself to the somewhat unusual view that the Atlantic (alkaline) magma is the typical world-magma of the depths, and that the Pacific magma is a special variety due to differentiation by orogenic movements. This is in absolute contradiction to the trend of modern opinion, especially in America.

The structures of continental masses and mountain chains are compared and contrasted, and the present plan of the surface is mainly attributed to Mesozoic geosynclinals. The account of the structure of the Alpine chains is specially clear, and brings out well the results of recent work in establishing the southward-folding of the Eastern Alps and the Dinaric chains. The Alpine mountain system in general is interpreted as the boiling over of a geosynclinal between the jaws of a vice, as figured by Suess, but it is made clear that the

boiling over took place outwards in both directions. The Pyrenees, Alps, Carpathians, and Balkans, and perhaps the Caucasus form the northern limb, thrust northwards, while the Atlas, Apennines, Dinaric chains, Taurus and Iranian arc form the southern limb, thrust southwards. The connexion between the Atlas and Betic Cordillera at the Straits of Gibraltar is abandoned, and both chains are considered to run out into the Atlantic, towards the Azores and Antilles. Another unorthodox view is that the Appalachians are the direct continuation of the Caledonian chains of Norway and Scotland. For this little evidence is given, and we note here a tendency that prevails among nearly all writers on this subject, namely, to mix up mountain ranges of quite different ages, if only the directions coincide.

The general structure of all the principal mountain chains and of the continental blocks of the world is considered in more or less detail. It is impossible here to discuss the many interesting points raised. It must suffice to say that the author finally comes to the conclusion that the present plan of the earth consists of solid continental blocks, each surrounded by an orogenic ring; these blocks are eight in number, two of them being now submerged beneath the Pacific; the rest form the existing continents, Eurasia, Africa, Indo-Australia, North America, South America, and Antarctica. These continental blocks form an octahedron whose edges are the orogenic geosynclinals, and of which two of the corners are situated, one in the Azores, at the crossing of the Mediterranean geosynclinal and the central ridge of the Atlantic, which is regarded as another principal orogenic zone, and the other somewhere in the Sunda Archipelago. The point in the Azores is the apex of the land-pyramid, the other the apex of the water pyramid, or hemisphere, which together form the octahedron. All this is very nicely worked out, and then, finally, in the last two pages, the author seems strongly inclined to go back on himself and to pin his faith to the old tetrahedral theory of Lowthian Green.

With regard to the prime cause of earth-movements in general, and mountain building in particular, the theory of isostasy in its prevailing form is rejected, everything being referred to simple contraction of the earth, and attention is directed to the great diminution in the size of the earth, which must have accompanied the folding and compression of originally horizontal strata. It is calculated that the reduction of the earth's radius since the beginning of Palæozoic times must have amounted to several hundred miles.

Whatever opinion we may hold as to the value of the ideas set forth and the conclusions drawn, there can be no doubt that the book is very well written and will be of considerable value as a summary of the ideas now prevailing among continental geologists on this subject.

R. H. R.

THE STUDY OF GEOLOGICAL MAPS. By GERTRUDE L. ELLES, D.Sc., Fellow of Newnham College, Cambridge. pp. 74, with 7 plates and 64 figures. Cambridge University Press. 12*s*. net.

GEOLOGISTS and teachers of geology in England will welcome this small book from the pen of so experienced a teacher and field worker as Miss Elles, and the more so since, as stated in the preface, it is based on lectures given by her for many years to honours students in geology, and has therefore been already put to the proof.

The first three chapters are given up to the exposition of topographical maps in their relation to geology, and full emphasis is given to the paramount importance of surface relief in the analysis of geological maps. One would perhaps expect this from an author whose work has been chiefly in the more rugged parts of these islands, but it is none the less commendable from the fact that such emphasis is frequently lacking in other works on geological maps.

The remainder of the book describes and illustrates methods of solving the problems of dip, thickness, relative age of strata, etc., from a geological map. The more complicated forms of outcrop given by folds, faults, overthrusts, and by igneous rocks are dealt with as fully as space permits. The great feature of the book is the frequent quotation of examples of the various types of formation to be found on the maps of the Geological Survey and the description of special areas on those maps. Full use is made of footnotes for reference to authorities or maps, so that the private student is introduced to the proper literature for fuller study.

In the solution of the problems recourse is had to the graphic methods of Harker, and these are illustrated with diagrams. The graphic constructions are dealt with in an appendix to the third chapter, and one is inclined to think that it is too condensed for the average reader who cannot have the benefit of personal demonstration. Experience leads one to believe that most students of geology find more difficulty in solving the problems of solid geometry that arise from geological maps than in anything else and a more detailed treatment would have added to the value of the book.

A final chapter on the interpretation of geological maps is excellent but all too brief, and tables of symbols and of the ordinary trigonometrical functions are added.

The book is very well illustrated with diagrams, sections, and maps, and a series of plates of block diagram drawings helps considerably in expounding the relation between surface relief and geological phenomena. After the excellence of the text-figures one is somewhat surprised to find the folding map at the end to be one of the less useful productions of the Ordnance Survey, exhibiting most prominently the two great faults of an irregular contour interval and heavy overprinting. The book is strongly bound and almost entirely free from printing errors, well up to the standard of the other books in the Cambridge Geological series. It is noteworthy,

however, that in order to accommodate the text-figures, the length of the lines has had to be increased, and it is not so easy to read as the other books.

To some extent the book may be regarded as complimentary to Harker's *Geological Map-reading*, and should therefore find many readers who require a less rigorous and theoretical treatment of the subject. The reviewer feels it necessary to point out, however, that in these two books on the study of geological maps we have but the latter half of the subject, the first half being the mapping in the field. To geologists in England, more or less adequately served by the maps of the Geological Survey, this may not appear to be of prime importance, but to anyone engaged in work in other countries, or in training people for such work, the need of an up-to-date text-book on geological field-mapping is very evident indeed. It is to be hoped that accomplished field workers such as the authors of these two books will consider that need and take steps to supply it.

F. D.

THE TIN RESOURCES OF THE BRITISH EMPIRE. By N. M. PENZER. pp. 358, with plates, maps, and charts (not numbered). London: W. Rider & Son, Ltd. 1921. Price 15*s.* net.

AS stated in a general introduction by Mr. J. S. M. Ward, this volume forms one of a series dealing with the raw materials of industry, and unlike the rest of the series it deals only with the British Empire; the reason for this is that the amount of information available is very great, and it is hoped that a second volume on the tin supplies of other countries will appear at a later date. The author has evidently ransacked very thoroughly the literature of tin mining, which, as shown by the bibliography recently published by Mr. and Mrs. Hess, for the Smithsonian Institution, is of vast bulk. In the nature of things the accounts given of the different districts vary in scope and value, since our knowledge of some of them is complete and detailed while in other cases it is vague and scrappy. This is due to the different points of view of those who have attempted to describe them. The study of a book of this kind serves to bring out very strongly the urgent need for a more systematic scientific training for mining engineers, or perhaps, to express it better, the need for a class of scientific mining geologists to supplement the work of the engineer. Only when this is brought about shall we attain to consistent and scientific descriptions of the mineral deposits of the world, especially of its more remote regions. The author has made good use of the material available, and has succeeded in giving an interesting and readable account of his subject, supplemented by many statistics, with maps and plans, and a bibliography of some forty-five pages, arranged topographically, is a valuable addition to the book.

THE WEST RIDING OF YORKSHIRE. By BERNARD HOBSON, M.Sc., F.G.S., xii + 188 pp., with 48 illustrations (not numbered), 7 diagrams, and 2 coloured maps. Cambridge University Press. 1921.

THIS, the latest addition to the well-known series of Cambridge County Handbooks, maintains the standard of its predecessors, and comprises a useful description of the natural and artificial features of the area under review. In the West Riding of Yorkshire the study of geology is of supreme importance from the commercial point of view, and the Coal Measures still present many unsolved problems of a technical character. On the theoretical side there are still questions of absorbing interest, as shown, for example, in a recent illuminating address by Professor Marr. The exact age of the oldest rocks of all, the Ingletonian series, is still unsettled, but there can be no possible doubt from their structures, lithological characters, and degree of alteration, that they are of very early date. These, together with the Lower Palæozoic rocks, have evidently been crushed up against a still more ancient mass, as so clearly shown by Professor Marr, and it is the nature of this ancient horst under the northern Pennines that provides such an interesting subject for speculation by theoretical geologists. Another still unsolved problem of a cognate character is the reason for the great change in thickness of the Lower Carboniferous at or near the Craven faults; this also is undoubtedly tectonic in its origin, and is a striking example of an abrupt change of facies. Space, however, will not permit of a further discussion of the features of the underground or superficial geology of this area. In this book the author gives a clear account of the topography of the Riding, and its dependence on geological structure, and his account of the special characteristics of the limestone regions will be tantalizing to those not personally acquainted with them.

With regard to the coloured geological map here provided, we can only say that it is simply deplorable, being thoroughly badly produced, and full of the most glaring errors. We cannot understand how the Cambridge University Press could allow such a thing to be issued under its auspices.

ORE DEPOSITION IN THE BOLIVIAN TIN-SILVER DEPOSITS. By W. MYRON DAVY. Economic Geology, vol. xv, 1920. pp. 463–96, with 2 plates and 4 text figures.

THE author discusses previous work on the tin-silver deposits of the Cordillera Real and its south-eastern extension to Potosí. He shows that the whole of the tin mineralization was approximately contemporaneous and that the lodes can be divided into three types: (*a*) tin-tourmaline lodes of the high temperature zone, without silver; (*b*) tin-silver lodes of the intermediate zones; (*c*) silver lodes without tin. Each type is correlated with and due to igneous activity,

type (*a*) being in and near deep-seated Tertiary granites, type (*b*) associated with intrusive porphyries, and (*c*) with extrusive lava-flows. A notable feature in type (*b*) is the abundance of stannite, which by oxidation has given rise to large deposits of wood-tin. Bismuth minerals are also abundant, but the author does not mention wolfram, which has of late been largely mined in this area. A brief reference is made to the occurrence of argyrodite and other germanium minerals. The origin of the ores by differentiation of igneous magmas is discussed, and the unusual association of tin and silver is attributed to incomplete differentiation before eruption. The author considers that the ore-deposits of this area offer a favourable field for future development, though mining is hindered by the great height of the country and the consequent severity of the climate.

R. H. R.

Laterit in West-Australien. By J. Walther. Zeits. d. Deuts. Geol. Ges. Vol. lxvii, 1915, pp. 113–32, with 2 plates and 1 text-figure.

A careful examination of the laterite region of West Australia in 1915 and a comparison of it with many other regions have led the author to some general conclusions. In this paper he expresses his definite opinion that laterization is not a phenomenon characteristic of the present climate of moist tropical regions, as stated or implied by many writers. Professor Walther considers that laterization went on during a past climatic phase, when there was a very well-marked alternation of annual extremes of drought and rainfall. This he supposes to have occurred in the "diluvial period", whatever that may mean. As a matter of fact, this conclusion, as to the necessity for strongly accentuated wet and dry seasons for laterization, was reached many years ago by Indian geologists.

This paper gives a graphic account of the peculiar topography and dry "lakes" of the more arid parts of Western Australia, and should be of service to all those interested in the subject.

A Geological Excursion Handbook for the Bristol District. By S. H. Reynolds, Sc.D., F.G.S., Second edition. pp. 224, with 50 figures. Bristol: J. W. Arrowsmith, Ltd. Price 5*s*. net.

We observe with pleasure that it has become necessary to issue a second edition of this admirable handbook, first published in 1912. In view of much recent work on the geology of the Bristol district, a large number of small additions to and corrections of the text have been made, and five new illustrations are included. It is impossible to exaggerate the usefulness of books of this kind, written by competent authorities, and in this case the name of the author is a sufficient guarantee of adequate treatment. The Bristol district